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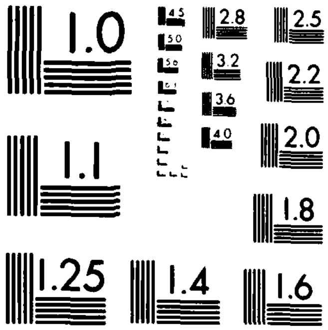
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INSTALLATION RESTORATION PROGRAM

PHASE II
PROBLEM CONFIRMATION AND QUANTIFICATION

MYRTLE BEACH AIR FORCE BASE,
SOUTH CAROLINA

VOLUME 1

Prepared by

Center for Environmental Measurements
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Occupational and Environmental Health Laboratory
United States Air Force
Brooks Air Force Base, Texas

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contamination and probable migration of contaminants beyond the DOD installation boundaries.

The activities of Phase I at Myrtle Beach Air Force Base were completed by Engineering Science, Inc., and recommendations made for Phase II of the program. The on-site portion of Phase I was performed at Myrtle Beach Air Force Base June 29 through July 2, 1981. The recommendations for Phase II were included in a Phase I report issued in October, 1981. The specific goal of Phase I at Myrtle Beach Air Force Base was to identify the potential for environmental contamination from past waste disposal activities and spills and to assess the probability of contaminant migration beyond the installation boundary.

The Research Triangle Institute (RTI) was directed by the Occupational and Environmental Health Laboratory (OEHL), Brooks Air Force Base, Texas, in May, 1982, to review the Phase I report prepared by Engineering Science, Inc., to conduct a presurvey for Phase II of the Installation Restoration Program at Myrtle Beach Air Force Base, South Carolina, and to define the best approach to be utilized for accomplishing the requirements of Phase II. Accordingly, RTI personnel and an independent hydrogeology consultant reviewed the Phase I report and visited Myrtle Beach Air Force Base on August 2 through 3, 1982. After the visit, a report was submitted to Brooks Air Force Base which summarized the discussions held with Air Force personnel and presented two plans for Phase II of the IRP program at Myrtle Beach Air Force Base. Subse-

INTRODUCTION

The United States Air Force, due to its primary mission, has long been engaged in a wide variety of operations dealing with toxic and hazardous materials. The primary Federal legislation governing disposal of hazardous materials is the Resource Conservation and Recovery Act (RCRA) of 1976, as amended. To assure compliance with these hazardous waste regulations, Department of Defense (DOD) developed the Installation Restoration Program (IRP). The current DOD IRP policy is contained in Defense Environmental Quality Program Policy Memorandum (DEQPPM) 81-5, dated 11 December 1981 and implemented by Air Force message dated 21 January 1982. DOD policy is to identify and evaluate past hazardous material disposal and spill sites and to control the migration of hazardous materials from those sites. The IRP will be the basis for response actions on Air Force installations under the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as clarified by Executive Order 12316.

The IRP has four phases, consisting of Phase I, Initial Assessment/Records Search; Phase II, Confirmation and Quantification; Phase III, Technology Base Development; and Phase IV, Operations/Remedial Actions. The intent of the IRP as applied to MBAFB is to identify report and correct potential environmental deficiencies which could result in groundwater

TABLE 2.
RECOMMENDED REMEDIAL MEASURES/ALTERNATIVE ACTIONS TO BE PERFORMED AT IDENTIFIED SOURCE AREAS WITHIN MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA

Identified Potential Source Area	Recommended Remedial Measures/ Alternative Actions*							
	1	2	3	4	5	6	7	8
Fire Training Areas #1 and #2			X		X	X	X	X
Landfill #3/ Weathering Pit #2			X	X	X	X	X	X
Fire Training Area #3			X		X	X	X	X
Weathering Pit #1			X		X	X	X	X
POL Fuel Spill Area			X		X	X	X	X
Landfills #1 and #4			X	X	X	X	X	X
Flight Line Area				X	X	X	X	X
Pipe Line Spill Area			X	X	X	X	X	X

*Subject to change depending on results of groundwater and surface-water monitoring.

Alternative References:

1) Removal or in-situ treatment of contaminant source materials
2) Intercept and treat contaminated groundwater
3) Monitor downgradient and upgradient groundwater quality
4) Monitor surface-water quality in nearby drainage ditches
5) Conduct thorough area-of-review for improperly abandoned on-base wells
6) Establish and/or maintain vegetation cover
7) Prohibit installation of shallow wells and regulate design and construction of deep wells
8) Restrict land uses which could increase the potential for contact with contaminants in affected areas. (The actual restrictions would depend upon the intended use, the nature of the land area and the contaminants present, and only can be determined on a specific c se by case base.)

The Pipeline Spill Area differs from other sites in that a recent (1981) and large (124,000 gallons) spill of jet fuel has caused high-level contamination within shallow sediments, to the extent that a separate phase fuel layer floats on top of the water table. Consequently, Findings 1, 2, and 4 do not apply to this site; Findings 3, 5, and 6 do apply.

Owing to the shallow nature of groundwater contamination at MBAFB, it is anticipated that relatively low-cost alternative measures can be used to effectively insure the objective of "preventing adverse impacts to human health and the environment." A listing of alternatives, along with the specific measures that are recommended at each of the sites are presented in Table 2.

5) Major groundwater-supply aquifers beneath the Myrtle Beach area are not likely to be affected by shallow groundwater contamination at MBAFB because:

   . Important aquifers are artesian, and are overlain by fairly extensive confining clay units

   . The artesian aquifers are recharged primarily in outcrop areas, which lie inland from MBAFB

   . Water-quality data indicate that contaminants have not moved appreciably downward within the shallow deposits.

6) The quality of water from shallow domestic wells in the vicinity of MBAFB (if such wells exist) is probably not threatened by the identified source areas; the contaminants are mostly intercepted by drainage ditches that discharge to the Intracoastal Waterway and the Atlantic Ocean, and the data suggest that the extent of lateral migration within the shallow system is probably limited. It has been determined that the City of Myrtle Beach is committed to using the Intracoastal Waterway as a source of drinking water; thus, there is reason for concern about discharge into this system. Feasibility studies have been performed and a pilot plant study has demonstrated that a sufficient supply of fresh water can be obtained for consumption with treatment by ozonation. The intake for the water supply will be near Tenth Avenue, North, and construction may start in early 1986. The wells presently used for the city's water supply will likely be maintained for make-up water during peak demand. (Pelletier, 1985) Accurate determination of the potential impact which each discharge may have on the uses of Intracoastal Waterway water would require additional investigations. Such investigations could include, for example, sampling and analysis of drainage ditch water and determination of dilution factors from the point of discharge to the point of usage.

   (Pelletier, M., 1985. South Carolina Water Resources Commission, Conway, S. C. Personal communication.)

- Possible increases in biodegradation rates within the more aerated sediments.

3) Contaminants (both organic and inorganic) are most concentrated within the upper water-table sediments, (upper 15 feet) and do not appear to have appreciably degraded groundwater quality within the lower water table or the shallow artesian unit. This distribution may be a result of confining clay layers that reduce or prevent vertical migration of contaminants into lower zones, and/or reductions or reversals in vertical hydraulic gradients during dry periods, which could periodically favor upward movement of groundwater and dissolved constituents.

4) Distinguishable "plumes" of contamination are not generally observed in the vicinity of source areas because:

   - Drainage ditches exert a strong influence over shallow groundwater flow patterns and, thus, often tend to intercept contaminants before they have moved an appreciable distance from the source area

   - It is likely that most source contaminants were introduced into the subsurface as pulses rather than at a steady rate and, therefore, may travel within the shallow groundwater system as slugs, rather than a well defined plume

   - Flow patterns beneath several of the sites are substantially altered under varied weather conditions, resulting in erratic contaminant migration

   - Contaminants within potential plume bodies may be periodically or continually depleted as a result of high water-level flushing and/or relatively rapid environmental attenuation within shallow deposits.

source area relationships, and factors controlling groundwater flow and/or contaminant migration. There was a high degree of similarity in conditions observed at each of the sites, except the Pipeline Spill Area (PSA). These common findings (i.e., applicable to all areas except PSA) are as follows:

1) Practices and/or events at the identified sites have resulted in varying degrees of low-level (generally less than one milligram per liter) groundwater degradation by one or more volatile organic compounds; water-quality alteration by inorganic compounds is noticeable (although minor) in areas hydraulically downgradient from landfills. Affected groundwater does not appear to be used for human consumption, and there are no standards specifying maximum permissable levels of the organic-type contaminants that were found. Ambient Water Quality Criteria (AWQC) for freshwater organisms do list acute and chronic toxicity levels for many of the compounds that were detected, and in almost all cases, observed concentrations were well below both of these limits.

2) Sites having relatively clay-rich surficial sediments (e.g., Weathering Pit #1 and Fire Training Area #3) tend to have higher concentrations of organic compounds than sites with more sand-rich surface deposits. This trend could simply reflect differences in initial water-quality conditions resulting from the various practices and events. However, the trend may result from differences in how various sediments accommodate contaminants, possibly reflecting:

   - Less extensive "flushing" of clays during high water-level periods
   - Lowered contaminant mobilities in clay-rich deposits
   - More extensive degassing (and escape) of volatile compounds from relatively well-aerated sand sediments

TABLE 1.
INVESTIGATIVE MEASURES UTILIZED AT IDENTIFIED POTENTIAL SOURCE AREAS AT MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA

	IDENTIFIED CONTAMINANT SOURCE AREAS							
Investigative Measure	Fire Training Areas #1 and #2	Landfill #3/ Weathering Pit #2	Fire Training Area #3	Weathering Pit #1	Landfills #1 and #4	POL Area	Flight Line Area	Pipeline Spill Area
Review of Existing Subsurface Data	NA	NA	NA	NA	NA	Na	NA	yes
Preliminary Site Inspection	yes	yes	yes	yes	yes	yes	yes	yes
Inspection of Aerial Photographs	yes	NI	yes	NI	NI	NI	NI	NI
Surface Geophysical Surveys	none	none	none	none	none	1	1	2
Hand Auger/ OVA Inspections	34	none	11	none	none	29	none	6
Soil Borings	14	11	7	11	12	6	4	none
Monitor Wells	9	8	5	6	7	5	4	none
Well Points	none	8	none	4	none	none	none	none
Water-Level Measurements	3 sets	3 sets	3 sets	3 sets	3 sets	3 sets	2 sets	none
Lab Analyses of Groundwater Samples*	2 sets	3 sets	3 sets	3 sets	3 sets	3 sets	2 sets	none
Field Analyses of Groundwater Samples*	2 sets	3 sets	3 sets	3 sets	3 sets	3 sets	2 sets	none
Falling-Head Permeability Analyses	none	1	1	1	none	1	none	none

NA = No data available
NI = No data inspected
* Analyses performed on samples from selected monitor wells.

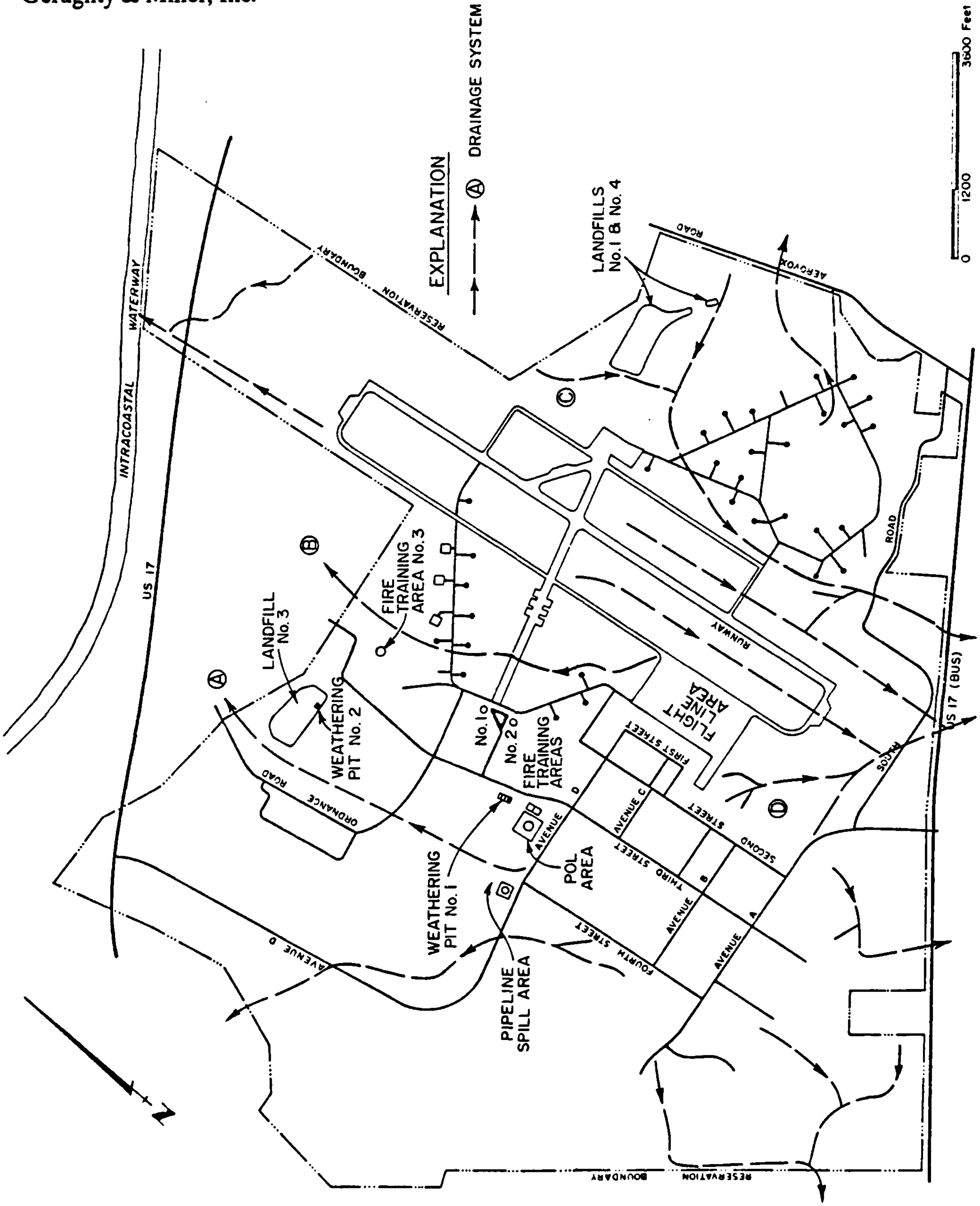

Figure 1. Identified Potential Source Areas and Important Drainage Ditch Systems at Myrtle Beach Air Force Base, South Carolina

SUMMARY

Pursuant to the Installation Restoration Program (IRP) Phase II Objectives, drilling, soil-sampling, and groundwater monitoring programs were conducted at seven of the potential contaminant source areas that have been identified within the boundaries of Myrtle Beach Air Force Base (MBAFB); these areas include Fire Training Areas #1 and #2, Landfill #3/Weathering Pit #2, Fire Training Area #3, Weathering Pit #1, POL Fuel Spill Area, Flight Line Area, and Landfills #1 and #4 (see Figure 1 for approximate source area locations). An additional site, the Pipeline Spill Area, was also evaluated using existing subsurface data, hand-auger/OVA results, and findings from a surface geophysical survey that was conducted to delineate plumes of high-conductivity substances. A listing of the types and numbers of investigative measures that were utilized in each of the identified areas is presented in Table 1.

All available data were then evaluated to define important site hydrogeologic conditions including: the textural composition of shallow sedimentary deposits, hydraulic head relationships between upper and lower water-bearing zones, groundwater flow patterns within the water-table aquifer, groundwater quality trends, contaminant/

Groundwater	The water contained in saturated, interconnected pores below the water table.
Hydraulic Gradient	The rate of change of pressure head per unit of distance of flow at a given subsurface point.
Incised	A stream meander or notch that has downcut or entrenched into the surface during, and because of, relative uplift of the surface.
JP-4	Jet propulsion fuel -4.
Leachate	A solution of water and soluable waste constituents.
OVA	Organic vapor analyzer.
Permeability	The property or capacity of a porous rock, sediment, or soil for transmitting a fluid without impairment of the structure of the medium; it is a measure of the relative ease of flow under unequal pressure gradients.
POL	Petroleum, oils, and lubricants.
TOC	Total organic carbon.
TOX	Total organic halogen.
Toxicity	Relating to, or caused by poison or toxin.
Volatile Component	A dissolved chemical constituent in groundwater that has a tendency to volatilize when exposed to the atmosphere.
Water Table	The surface between zone of saturation and the zone of aeration; the upper surface of a body of unconfined ground water along which the pressure is equal to that of the atmosphere.

GLOSSARY OF TECHNICAL TERMS

Aeration	The supplying of air and other gases to the soil pores.
Ambient	An encompassing environment; surrounding all sides.
Anomaly	A deviation from uniformity or regularity in geophysical quantities; a difference between observed and computed value.
Aquifer	Rock or sediment which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.
Artesian	Groundwater confined under hydrostatic pressure.
Attenuation	To make thin in thickness, density, or force; to reduce the severity, virulence, or concentration of.
Degradation	The wearing down or away, and the general lowering or reduction, of the earth's surface by the natural processes of weathering and erosion.
Delineate	A step in map compilation in which mapworthy features are distinguished and outlined on various possible source materials or are visually selected.
Evapotranspiration	Loss of water from a land area through transpiration of plants and evaporation from the soil.
Gradient	The change in value of one variable with respect to another variable; especially vertical distance with respect to horizontal distance, or geophysical properties such as gravity, temperature, magnetic susceptibility, or electrical potential with respect to horizontal distance.

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quently, the Air Force accepted one of the proposed plans and asked RTI in September, 1982, to carry out the Phase II field evaluation at Myrtle Beach Air Force Base.

PURPOSE AND SCOPE OF THE PHASE II FIELD EVALUATION

The purposes of the Phase II field evaluation program at Myrtle Beach Air Force Base have been to:

1) Determine if environmental contamination has resulted from waste disposal practices;

2) Make recommendations for actions necessary to fully evaluate the magnitude and extent of contamination should contamination be found;

3) Evaluate the potential for air pollution problems at hazardous waste disposal sites;

4) Make site-specific recommendations for actions necessary to mitigate adverse environmental effects of existing contamination problems;

5) Suggest potential ways of restoring the environment to as near a normal level as practical;

6) Identify actions required to comply with existing South Carolina Environmental Regulation requirements at hazardous waste disposal sites; and

7) Suggest a future environmental monitoring program to document conditions and future discharges at sites identified.

Research Triangle Institute and Geraghty and Miller, Incorporated, a subcontractor to RTI, performed the Phase II field evaluation program at Myrtle Beach Air Force Base during October, 1982, to October, 1983. This report summarizes the various activities performed at the base during that one year period, and presents recommendations for the Air Force Phase IV - Operations/Remedial Actions Programs.

HISTORY OF MYRTLE BEACH AIR FORCE BASE

Myrtle Beach Air Force Base (MBAFB) is located in northeastern South Carolina, approximately 85 miles north of Charleston and 60 miles south of Wilmington, North Carolina. Myrtle Beach Air Force Base is located in Horry County and is situated adjacent to the Atlantic Ocean.

Prior to 1940, a municipal airport was operated at MBAFB. In 1940, preparations were made to improve the Myrtle Beach Municipal Airport so that it might be incorporated into the national defense program. The area was first used by the Army Air Corps in June 1940 when the Third Observation Squadron arrived at the municipal airport to conduct firing practice along the ocean front and to map and photograph the entire area.

In March 1942, men arrived from the Savannah Army Air Base to establish and operate a bombing and gunnery range detachment. Throughout World War II, numerous units were trained on the range as a prerequisite for going overseas. The training program consisted of several phases; bombardiers practiced bombing and gunners were given schooling in fixed and flexible gunnery. The range at Myrtle Beach was composed of some 100,000 acres in nine tracts, three of which were owned and six were leased by the government. The government tracts containing an aggregate of 97,300 acres were known as the Myrtle Beach, Conway and Georgetown areas. The Myrtle Beach tract, located in Horry County was located between the Atlantic Intracoastal Waterway and Conway. The Georgetown area contained a demolition range and two bombing ranges, while the Conway area had one demolition range, three bombing ranges and a machine gun and rifle range.

At the end of World War II, over 114 buildings had been built and the entire base was connected by a network of access and secondary roads. All of the taxiways were laid out in a dispersal pattern so as to minimize any direct hits on aircraft which were parked. Fueling areas were also dispersed.

During the winter of 1945 to 1946, the mission of Myrtle Beach became one of recruitment and support of special activities. The Civil Air Patrol, the National Guard and the United States Military Academy were among the organizations which utilized the field for encampments and various other activities which were supported by the base. November 1, 1947, was the date the base was inactivated and at that time the runways and tower were turned over to the City of Myrtle Beach for use as a municipal airport.

During the period from 1947 until 1954, the city pursued the reactivation of the base with both the US Army and Air Force. During that period the city operated a municipal airport and leased a small portion of the property adjacent to the terminal to Aerovox Corporation, a manufacturer of ceramic capacitors.

During this period, the city restricted access and scavenging at the site. Other commercial concerns which rented property at that time were:

- o Boston Braves training camp located at the south end of the runway
- o Turkey Farm
- o Piedmont Airlines
- o Hotdog Cooker Company
- o Automobile race track utilizing the old motor pool area and southeast loop of revetment.

In June 1954, the Air Force accepted the City's donation of the airport. At that time, the base encompassed over 4,400 acres. Most of the World War II buildings were demolished with the new cantonment area and flight line constructed on the western portion of the base property.

In 1955 before the base was fully operational, the Seven Twenty Seventh Aircraft Control and Warning Squadron arrived at Myrtle Beach to become the installation's first tenant unit. Shortly thereafter, the 4434th Air Base Squadron was established as the housekeeping unit. This unit was subsequently replaced by the 345th Fighter Day Wing which was in 1958 redesignated the 345th Tactical Fighter Wing. The 354th

Tactical Fighter Wing is under the direction of the Tactical Air Command (TAC). It is composed of three operational squadrons, five maintenance and support squadrons, and the 354th Combat Support Group. The 354th Combat Support Group provides base support for the tactical fighter wing. The 354th Tactical Fighter Wing is responsible for support of Myrtle Beach's various tenant units. This responsibility includes law enforcement, health care, administration, civil engineering, commissary, exchange and other services and facilities. The mission/functions of the major organizations at MBAFB are discussed in the Phase I report.

HISTORY AND DESCRIPTION OF SITES

Fifteen sites within the confines of the MBAFB were identified in the Phase I report as potentially containing hazardous material resulting from past activities. Included were weathering pits, fuel storage areas, fire training areas and landfills.

In order of decreasing potential for harm to the environment the fifteen sites are as follows. Also given are period of operation or date of spill or observation of contamination.

o Weathering Pit #2	1979-1981
o Myrtle Beach Pipeline Corporation Spill	1981
o Weathering Pit #1	1973-1978
o POL Bulk Fuel Storage Area	1963-1967
o Landfill #3	1964-1968
o Flight Line Contaminated Area	1977
o Fire Training Areas #1 and #2	1955-1964
o Fire Training Area #3	1965-1969
o Landfill #4	1968-1972
o Underground Waste Chemical Storage	1978-Present
o Landfill #1	1955-1960
o Landfill #2	1960-1964
o Landfill #5	1973-1974
o Fire Training Area #4	1970-1981
o Radioactive Vault	1959

Of the fifteen, ten sites were chosen for investigation. Excluded were the Underground Waste Chemical Storage Site and the last four sites on the list given above.

Weathering Pits

Air Force bases handling large quantities of jet fuel have one unique disposal problem which they have addressed utilizing "weathering pits." Weathering pits are constructed to expose spent fuel filters and other sorbent materials soaked in petroleum products to the open air and sunlight. This exposure results in loss by evaporation and chemical decomposition. The exposed materials are ultimately placed in landfills. There have been two weathering pits at MBAFB, both of which are no longer in use. "Weathering" is presently done in an area consisting of a concrete pad and appropriate drainage systems and is not of environmental concern. The oldest pit (#1) is located within Landfill No. 3.

The following is a summary of physical information with regard to the two old pits:

Pit No.	Use Period	Dimensions	Liquid Depth
1	1973-78	15' X 15'	12"
2	1979-81	50' X 55'	12"

Both weathering pits received quantities of waste oils, solvents and paint strippers. Weathering Pit #2 was cited by the South Carolina Department of Health and Environmental Control when they conducted a RCRA inspection on June 9, 1981. Weathering Pit #2 was found by RTI personnel to be in the form of a "pond" containing water, petroleum wastes and sludge. Prior to the start of the groundwater monitoring, the pond contents and surrounding and underlying soil were removed and taken to an approved landfill. The removal was performed independently of the IRP Phase II work and was carried out by Williams Trucking Company of Charleston Heights, South Carolina. The only evidence for Weathering Pit #1 is a difference in coloration of the soil and surface grasses at the actual site. These differences have no apparent significance for other than locating the pit.

Fuels and Oil Spills

The Phase I survey noted three previous Class III spills (exceeds 10 feet in any planar direction) and one reported visual observation. They were:

Spill Area	Year	Amout JP-4 Spilled Gallons
POL Bulk Fuel Storage	1963-67	10,000
Myrtle Beach Pipeline	1975	1,500
Flight Line (Bldg. 358)	1977	Unknown
Myrtle Beach Pipeline	1981	124,000

The POL area spill occurred between Tank 41103 and a 50,000 gallon tank which used to be adjacent to it. In 1975, a dragline struck and ruptured the 6-inch fuel supply line to the Myrtle Beach Bulk Storage Tank. The spill was contained and limited to 1200 square feet. No long term environmental damage was sighted. In 1977, the South Carolina Water Resources Commission was conducting a pump test adjacent to Building 358 (30 feet deep/10 gpm) and encountered POL contaminated groundwater for the entire 24 hour test period. No correspondence was sent to the base informing them of this information. Subsequent review of underground storage tanks, etc., fails to explain the source of the contamination.

The last spill occurred in 1981 when 124,000 gallons of JP-4 was accidentally released by Myrtle Beach Pipeline Co. (MBPC) near the Pipeline Bulk storage tank on leased land. French drains were installed by MBPC eleven days after the spill and they have recovered 24,000 gallons of fuel. The area of major contamination was 200 feet by 200 feet.

Fire Training Areas

Fire training areas are open areas where fuel and other petroleum wastes are spread on the ground and ignited and then extinguished by fire fighting personnel as part of their training. In the past, the fuel was simply spread on areas of ground surrounded by dikes; presently the areas are underlain by drain tile leading to oil/water separators and the soil is saturated with water before the fuel is added.

The Fire Control Department has operated four fire training areas since 1955, where petroleum based fires are set and thereafter extinguished. The following are specific designations for the individual training areas as well as their approximate operational period.

Fire Training Area	Period of Operation
1-2	1955-1964
3	1965-1969
4	1970-1981

The procedure utilized in fire training areas No. 1, 2 and 3 was to construct an earthen dike approximately 12 to 18 inches high in order to contain the fire and to pour the fuel onto the soil within the dike and to set the fuel on fire. Chemicals were then applied to extinguish the fire. As air pollution regulations became more stringent in the mid 60's, the fire training exercises were curtailed severely. This schedule has in turn been modified until at the present time there are two fire training exercises per quarter and the fuel utilized is uncontaminated JP-4 fuel. The current procedure utilized in area No. 4 is to flood the area with 1500 gallons of water and then to place 300 gallons of JP-4 on top of the water surface. The advantage to this procedure is that it minimizes the percolation of the fuel into the soil. The other reason this procedure is being followed is that the fire department must purchase the JP-4 and the water flooding procedure minimizes overall fuel consumption.

To extinguish a typical fire, the fire department uses approximately 50 gallons of a fire control agent, AFFF mixed with an additional 1500 gallons of water. The concentrated agent has a chemical oxygen demand approximating 400,000 milligrams per liter (mg/l), which for a typical fire training exercise would be equivalent to 166 pounds of COD. The chemical AFFF has been used since 1972. Previous to that a protein foam was utilized as an extinguisher.

Landfills

Five separate landfills have been used for disposal of solid hazardous and non-hazardous wastes at MBAFB. Each was used for disposal of general refuse; the mode of operation was trench and cover with the refuse burned in Landfills #1 and #2. Since 1974, all municipal solid waste generated on base has been hauled off base by a private contractor.

Landfill #1 is situated in the northeastern portion of the Myrtle Beach property, encompassing approximately 9 acres. All landfilling was accomplished by a trench, burning and cover operation. Trenches were normally constructed approximately 16 feet in width and an average 5 to 10 feet deep at this particular location because of its relatively high elevation. Ordinarily on hitting the ground water table, a trench would be cut no deeper since it would interfere with the overall landfilling operation. After the landfill was closed, the base golf course was constructed over Landfill #1.

Landfill #2 is situated in the northwest section of the base northwest of the POL area, encompassing approximately six acres. The eastern portion of the site is being utilized as a hardfill area (construction debris). The problem with this procedure is that depositing hardfill on top of the closed landfill disturbs the surface drainage pattern and can cause ponding of stormwater with the increased potential for leachate development.

Landfill #3 is located at the northeast corner of the base property. The site was approximately 12 acres and was constructed with the trenches trending from north to south. During the period of operation of Landfill #3, air pollution regulations at Myrtle Beach prevented the daily burning of solid waste. Therefore, Landfill #3 was the first landfill to be operated as a trench and cover operation with no burning. Any materials which found their way into the landfill would not have been destroyed and could possibly provide a source of potential future groundwater contamination.

The landfill operation was closed in 1968. In 1976, the base obtained permission from the State to landfill grease and scum from their anaerobic digesters in trenches which were constructed perpendicular (east to west) to the existing landfill trenches. The trenches were constructed approximately three feet deep with 18 inches of material from the digesters being placed in them. After dewatering, the trenches were closed and the site regraded.

Landfill #3 has been graded so that the surface runoff drains in either a southerly or westerly direction to ditches which abut the site. Visual observations made at the site indicate differential settlement and the need for regrading sections of the site to prevent the ponding of stormwater. Other portions of the site have been used as hardfill areas and for the disposal of sludge from the wastewater treatment plant drying beds. All of these materials have been placed in piles on the surface of the landfill and no attempt at regrading has been undertaken. These piles of material will disrupt established drainage patterns and increase the likelihood of additional leachate generation.

Landfill #4 was constructed on top of an area which served as a sand borrow pit. The trench orientation was generally north to south. Of the five landfills previously used, Landfill #4, because of its remote location, has not been utilized as a hardfill area and as such is completely vegetated with growth 12 to 24 inches high.

POLLUTANTS ANALYZED AT THE CONTAMINATED SITES

The groundwater samples collected from the contaminated sites were analyzed for pH, nitrate, sulfate, chloride, phenol, iron, manganese, sodium, arsenic, barium, chromium, lead, mercury, zinc, selenium, vanadium, specific conductance, total organic carbon, total organic halogen and volatile organic compounds. The samples collected were preserved and analyzed in accordance with U. S. Environmental Protection Agency and U. S. Geological Survey guidelines. The analytical procedures used are described in Appendix A.

FIELD TEAM

In order to perform the Phase II field evaluation program, Research Triangle Institute and Geraghty and Miller, Inc., assembled the following core team of professionals.

- R. K. M. Jayanty, RTI
- W. F. Gutknecht, RTI
- H. LeGrand, Consultant to RTI
- C. Smith, Geraghty & Miller, Inc.
- J. Sgambat, Geragthy & Miller, Inc.
- R. Wright, Geraghty & Miller, Inc.

The well drilling and surveying were performed by A. C. Borings (St. Matthews, South Carolina) and Moore, Gardner and Associates, Inc., (Surfside Beach, South Carolina), respectively. The on-site field sampling was performed at MBAFB during the period December, 1982 through June, 1983.

an aquifer, and the potential for aquifer degradation by extraneous substances, is the mechanism(s) by which an aquifer is recharged. Within the shallow water-table system, recharge is believed to occur primarily from precipitation that infiltrates surface sediments and percolates down to the water table. Where precipitation represents the only source of replenishment, aquifers tend to be subject to large water-level fluctuations, and may be drawn down excessively by long-term pumping, particularly during relatively dry periods. In areas where pumping has lowered water levels significantly, the shallow system may also receive recharge from nearby streams and other surface-water bodies (including the ocean) that are hydraulically connected to the aquifer. Because surface waters often contain dissolved and suspended substances that are undesirable in drinking water supplies, recharge by this mechanism can result in local degradation of groundwater quality (Zack, 1977).

Shallow artesian and semi-confined aquifers included in the water-table aquifer system, in the area of interest, are probably recharged primarily by leakage from overlying water-bearing units (i.e., the water table). Because the shallow artesian aquifers usually are localized (i.e., MBAFB, the Canepatch Formation is thought to be overlain by the Socastee Formation; Undifferentiated deposits may also be present in localized areas.

The Canepatch Formation is characterized by a rather wide range of sediments including clays, clayey to silty fine sands, and poorly sorted, medium to coarse sands. In areas surrounding MBAFB, as well as near-shore areas along most of the Grand Strand, the Canepatch Formation is overlain by the Socastee Formation. Sediments comprising this formation in near-coastal areas generally consist of well sorted, fine to coarse dune sands, but change to clays and clayey to silty fine sands in more inland areas. In the MBAFB area, Socastee deposits comprise most of the surficial sediments; although, in localized areas, the Socastee Formation may be capped by the fine to coarse sands, interbedded clays, and peats and peaty sands of the Undifferentiated Holocene deposits. An in-depth discussion of shallow sedimentary deposits will be presented in future sections regarding site-specific hydrogeologic conditions at MBAFB.

Aquifer Recharge

One of the more important factors controlling the volume of groundwater that can be regularly pumped from

The Bear Bluff Formation, where present, is overlain by the Waccamaw Formation, which is comprised of gray to brown sandy marl, and fine to medium sands that commonly become coarser toward the base. Information presented in Zack (1977) suggests that the Waccamaw Formation may constitute one of the more important Quaternary units comprising shallow water-table and artesian aquifers. As noted earlier, the Waccamaw Formation also can directly overlie the Peedee Formation, depending on the eroded expression of this unconformable contact.

Shallow artesian aquifers (confined groundwater zones), particularly within Quaternary sediments, generally do not persist over long distances. Although locally they may be developed and exploited as discrete hydrogeologic units, discussions presented in this report will regard shallow artesian aquifers as part of the water-table aquifer system.

Geologic units comprising upper portions of the water-table system, in ascending order, include the Canepatch and Socastee Formations and, in some areas, Undifferentiated Holocene (or Recent) sediments. Over large areas of Horry County, the Canepatch Formation forms the surficial deposits, with Socastee and Undifferentiated sediments being absent. However, in near-shore areas and in the vicinity of

According to Glowacz (1980), the Peedee Formation has an unconformable (erosional) contact with younger, overlying formations. Depending on the local nature of its buried, weathered surface, the Peedee can be directly overlain by either the Bear Bluff Formation (of Tertiary age) or the Waccamaw Formation (of Quaternary age). Water-table and artesian aquifers generally occur within the shallow Tertiary and younger sediments (Zack, 1977).

The Bear Bluff Formation is comprised of calcareous silts and sands, marls, sandy limestones, and possibly some dark clays (Glowacz, 1980; Zack, 1977). Information presented in Glowacz (1980) and Spigner (1977) suggests that this formation may represent one of the more important Tertiary units comprising shallow artesian aquifers. However, stratigraphic data presented in Zack (1977) raises some question as to whether or not Tertiary sediments reach appreciable thickness in the vicinity of MBAFB.

In some areas, the Bear Bluff Formation may be underlain by erosional remnants of the Duplin Formation, which was mainly comprised of sandy to silty limestones and calcareous, silty sands (Glowacz, 1980); however, this Formation probably is not present in appreciable thicknesses within the area of interest.

composed of dark-gray, clayey sand with horizons of calcareous clay and loose, shelly limestone or coquina. This formation lacks the calcareous sandstone layers that are common to the upper Black Creek Formation (Zack, 1977; Glowacz, 1980).

The Peedee aquifer system (within the Peedee Formation) is typically artesian in nature and is probably capable of producing large quantities of groundwater. This aquifer is sometimes used in conjunction with the subjacent Black Creek system as a source of potable water. However, development of the Peedee aquifer system tends to be fairly localized because the quality of groundwater within the Peedee system is variable, often being inferior to that of the underlying Black Creek system (Zack, 1977).

Clay layers situated toward the top of the Peedee Formation are also thought to impart short-term hydraulic independence between the Peedee aquifer system and the overlying, water-bearing units within the Tertiary and/or Quaternary systems. The top of the Peedee Formation is believed to be situated at an elevation of about -20 to -30 feet MSL (roughly 40 to 50 feet below the land surface) in the vicinity of MBAFB (Pelletier, 1983).

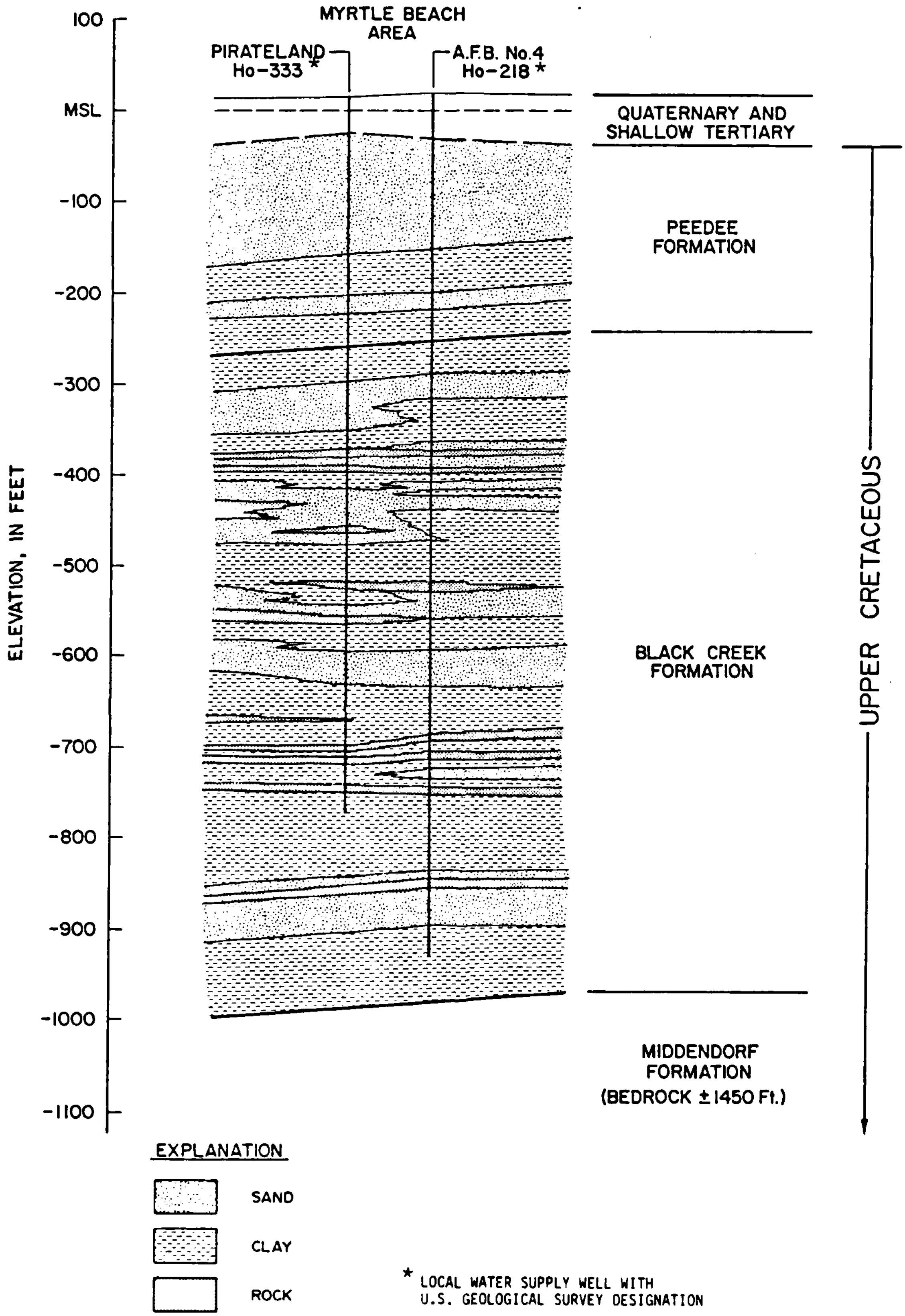


Figure 3. Generalized Stratigraphic Column for the Myrtle Beach Area, South Carolina

Source: Zack, 1977

containing the fluoride-bearing mineral collophane, are abundant in the upper third of the formation (Zack, 1977). The generalized stratigraphic column presented in Figure 3 indicates geologic relationships within the Black Creek and overlying formations.

The Black Creek aquifer system (within the Black Creek Formation) is the most important source of groundwater in Horry County, and is used for municipal, industrial, and domestic water supplies. This is an artesian (confined) aquifer system, which is hydraulically separated from the subjacent Middendorf system by a sequence of continuous and relatively impervious clay layers. Clay layers situated toward the top of Black Creek Formation are believed to also impart at least short-term hydraulic independence between the Black Creek and the overlying Peedee aquifer; i.e., groundwater within the two aquifer systems does not appear to move freely across aquifer boundaries when subject to short-term pumping stresses (Zack, 1977). The contact between the Black Creek and Peedee Formations is a ravinement or disconformity, generally occurring at an elevation of -200 to -300 feet MSL.

The Peedee Formation ranges from 250 to 400 feet in thickness throughout most of the Grand Strand, and is of both authors in order to more accurately describe the hydrogeologic conditions that probably occur beneath Myrtle Beach and near-inland areas.

The lowermost stratigraphic unit, the Middendorf (or Tuscaloosa) Formation, ranges from 300 to 500 feet in thickness and rests unconformably upon Pre-Cretaceous basement rock at an elevation of -1300 to -1500 feet MSL. The Middendorf Formation is comprised of cross-bedded, coarse sands with lenses of sandy to silty clay. Thick and continuous layers of well sorted, clean sands are also present, and it is probable that these units could provide relatively high groundwater yields. However, the Middendorf aquifer system (within the Middendorf Formation) contains salty water (250 mg/l or more of chloride) throughout all of the Grand Strand and possibly all of Horry County, and thus has not been developed as a groundwater supply (Zack, 1977). This formation appears to have an interfingering contact with the overlying Black Creek Formation at an elevation of -900 to -1000 feet MSL.

The Black Creek Formation ranges from 650 to 750 feet in thickness and is comprised of dark-grey clay interbedded with gray to white, fine to very-fine quartz sand. Continuous layers of hard, calcareous sandstone, possibly

TABLE 3.
LITHOLOGIC DESCRIPTIONS AND WATER-BEARING PROPERTIES OF GEOLOGIC FORMATIONS BENEATH THE MYRTLE BEACH AREA OF SOUTH CAROLINA
(Adapted from Zack, 1977, and Glowacz, 1980)

System	Series	Geologic Formation	Description of Sediments	Associated Aquifers	Water-Bearing Properties
Quaternary	Holocene	Undifferentiated	Light gray and buff, fine to coarse sands and interbedded clays, peats and peaty sands deposited under continental and nearshore conditions.	Shallow water-table and localized artesian aquifers.	Water often hard with relatively high iron and manganese. Primarily recharged by precipitation and subject to large water-level fluctuations.
	Pleistocene	Socastee	Fine to coarse sands, argillaceous and silty sands and clays; deposited under littoral, marsh, and estuarine conditions.		
		Canepatch	Clay, argillaceous, silty fine sand, and poorly sorted, medium to coarse sand; generally oxidized in upper part and unfossiliferous. Deposited under swamp, marsh, lagoon, and estuarine conditions.		
		Waccamaw	Blue-gray to yellow and brown sandy marl; gray to buff fine loose quartz sand, commonly coarse at its base; fossils sparse to abundant representing brackish to open marine environments.	Water-table and shallow artesian aquifers primarily in coastal Horry County.	Water often hard, having some iron and hydrogen sulfide odor. Fair to large yields. Important in Little River-Calabash area where freshwater from other formations is unobtainable.
Tertiary	Pliocene	Bear Bluff	Calcareous silts and sands, sandy limestones, and sub-arkosic sands, with fossils common. Deposited under open marine conditions.	Water-table and artesian aquifers.	Water usually of fairly good quality; may be hard with iron and hydrogen sulfide odor.
		Duplin	Sandy limestone, silty soft limestone, and calcareous silty sand with well preserved fossils. Occurs as erosional remnants. Deposited under open marine conditions.		
Cretaceous	Upper Cretaceous	Peedee	Gray to greenish-black calcareous, glauconitic clayey silts and fine-grained sands with thin beds of gray calcareous sand and hard sandy limestone.	Peedee aquifer system	Treatment for iron and sulfate removal required for municipal use. Yields are high.
		Black Creek	Gray to greenish montmorillonitic clays and thin beds of gray to white slightly glauconitic sand. Thin beds of hard, sandy limestone containing pyrite, lignite, and possibly collophane.	Black Creek aquifer system	Principal aquifer in the two-county area. Contains saline water in northeastern Horry County. Yields as high as 1000 gallons per minute have been obtained in Horry County. Fluoride is usually high.
		Middendorf	Light-colored cross-bedded kaolinitic sands with lenses of white massive kaolin. Lignite and pyrite common. Clays are non-calcareous.	Middendorf aquifer system	Contains salty water throughout area (possible exception along northwestern boundary of Horry County).
Pre-Cretaceous		Basement	Basement rocks (metamorphic crystalline complex).	None	None

References: Adapted from Zack, 1977; and Glowacz, 1980.

REGIONAL HYDROGEOLOGY

Stratigraphy

The Grand Strand and near-inland areas of Horry County are underlain by more than 1300 feet of sedimentary deposits that dip generally seaward and thicken toward the coast. These deposits, which are mostly unconsolidated, rest unconformably upon a basement complex of metamorphic and crystalline rocks (Zack 1977).

In ascending order, sedimentary deposits of the Myrtle Beach area have been segregated into the Middendorf, Black Creek, and Peedee Formations of Upper Cretaceous age; the Bear Bluff and Duplin Formations of Upper Tertiary age; and the Waccamaw, Canepatch, Socastee, and Undifferentiated Formations of Quaternary age (Glowacz, 1980; Zack, 1977). Lithologic descriptions and general water-bearing properties of these formations are presented in Table 3.

Geohydrology

The following discussions pertaining to the geology and general water-bearing characteristics of formations comprising sedimentary deposits are based on information provided in Glowacz (1980) and Zack (1977). Certain preferences have been given to the stratigraphic interpretations extensive tidal marshlands have developed along the coast and extend as much as 25 miles up the larger rivers. Fresh- to brackish-water swamps and bogs are also common throughout inland plains, especially in areas adjacent to small streams. These conditions, along with the potential for flooding during storm events, have promoted the development of an extensive system of man-made drainage ditches. Aside from directing surface runoff and overland flow to the tributaries of major drainageways, the ditches also act to dewater saturated or waterlogged sediments comprising marshlands and bogs. This effect has greatly improved the potential usefulness of land throughout parts of the Grand Strand and near-westward areas, including northern and western portions of MBAFB.

June to September. Average annual precipitation for the area is about 50 inches (Zack, 1977).

Topography and Drainage

The Grand Strand area lies entirely within the Atlantic Coastal Plain physiographic province and is generally characterized by relatively flat-lying topography. In the vicinity of MBAFB, and throughout much of the Grand Strand area, land surface elevations range from sea level to 30 feet or more above MSL.

Principal drainage within the Grand Strand and near-westward areas is provided by the Intracoastal Waterway and the Waccamaw and Peedee Rivers, which flow southwestward and empty into Winyah Bay; virtually all of the drainage emanating from northern and western portions of MBAFB enters the Intracoastal Waterway via small tributaries (see Figure 1). Drainage along coastal margins of the Grand Strand, including southern and eastern parts of MBAFB, is provided by small streams that flow directly to the Atlantic Ocean and discharge via swash channels and inlets.

Because of the low topographic relief and near sea level land elevations characterizing much of the area,

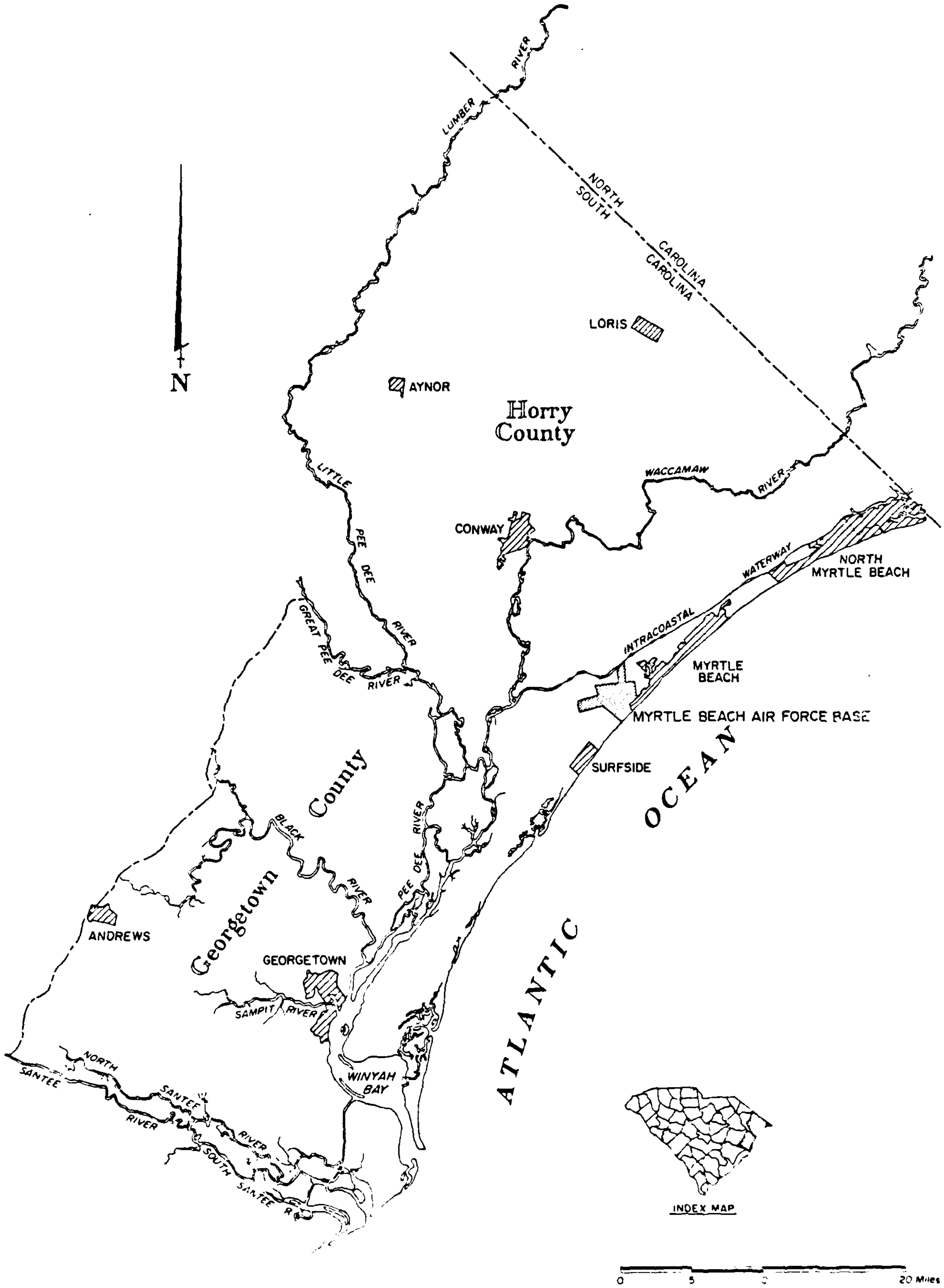


Figure 2. Location of Myrtle Beach Air Force Base, South Carolina

ENVIRONMENTAL SETTING

PHYSICAL GEOGRAPHY

Location

The Myrtle Beach Air Force Base (MBAFB), located in southeastern Horry County, South Carolina, is situated on a narrow strip of land about five miles wide, referred to as the Grand Strand. The Grand Strand is bordered by the Atlantic Ocean to the east and the Intracoastal Waterway and the Waccamaw River on the west, and extends roughly 69 miles from the North Carolina state line southwestward to Winyah Bay (see Figure 2).

Climate

The climate of the area is typical of subtropical humid zones with hot summers and mild winters averaging 79°F and 47°F, respectively (Engineering Science, 1981). The mean annual temperature of the area is about 65°F (Zack, 1977); the mean annual air temperature is also usually a good approximation of average shallow groundwater temperatures.

Precipitation is ample and fairly well distributed throughout the year, with maximum rainfall occurring from discontinuous horizontally), they may also receive significant quantities of lateral recharge from adjacent deposits.

Deeper artesian aquifer systems, including the Peedee, Black Creek, and Middendorf aquifers, are recharged primarily in outcrop areas, where water from precipitation or influent streams infiltrates aquifer sediments at or near the land surface, and moves down dip toward points of discharge (Zack, 1977). Aquifers recharged by this mechanism tend to have a more continuous supply of available groundwater and, barring contaminant sources within outcrop areas, are relatively well protected against degradation by extraneous substances; although, improperly abandoned wells can provide conduits for contaminant entrance. Deep artesian aquifers may also receive some vertical recharge via long-term leakage through overlying confining units, or from line-source areas where confining units are characterized by increased permeabilities. Such an area is believed to occur about ten miles inland from the coast, near the Horry-Georgetown County line, where the Black Creek aquifer apparently receives significant recharge from the overlying Peedee Formation (Zack, 1977).

As indicated in Figure 4, outcrop areas (recharge areas) for the Peedee, Black Creek, and Middendorf Formations are situated well inland of the Grand Strand area.

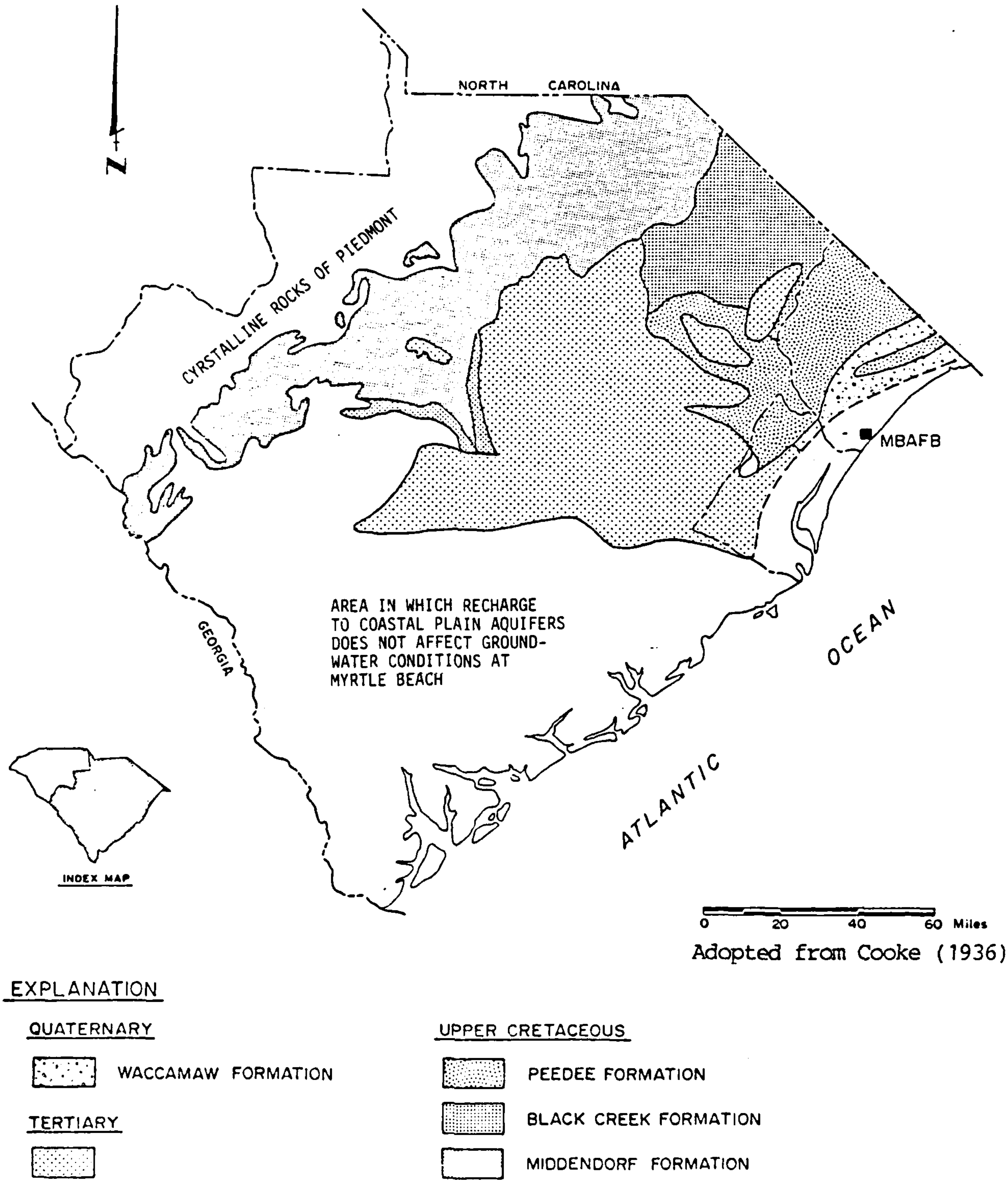


Figure 4. Approximate Outcrop Areas for Major Aquifer Systems Beneath the Myrtle Beach Area, South Carolina.

Source: Zack, 1977

Therefore, it is very unlikely that near-surface conditions in the vicinity of MBAFB would have an effect on water quality within these aquifers.

Water Quality and Groundwater Use

Information presented in Zack (1977) and Glowacz (1980) indicates that the Myrtle Beach area of Horry County is underlain by four main aquifer systems, in ascending order, the Middendorf, the Black Creek, the Peedee, and the combined shallow water-table and artesian systems. Except for the Middendorf, which contains salty water, all of these aquifers are known to contain water that is generally acceptable for domestic supplies, although some treatment may be required to reduce levels of undesirable constituents such as iron and sulfur. Typical water-quality for the Black Creek, the Peedee, and the water-table aquifer systems is indicated in Table 4.

The Black Creek aquifer constitutes the most important source of groundwater throughout Horry County, and is used for industrial, municipal, and domestic supplies. With the exception of fluoride, this aquifer typically yields water of good quality requiring little or no treatment before use, although concentrations of chloride, sodium, and dissolved solids tend to be fairly high. Natural fluoride concentrations commonly exceed the established Primary Drinking Water Standard of 1.4 to 2.4 milligrams per liter (mg/l).

TABLE 4.
TYPICAL GROUNDWATER QUALITY FOR THE BLACK CREEK, PEEDEE, AND WATER-TABLE AQUIFER SYSTEMS BENEATH THE MYRTLE BEACH AREA OF SOUTH CAROLINA
(all concentrations in milligrams per liter, unless otherwise specified)

	MBAFB No. 3 Well HO-226, Black Creek Aquifer System*	Eagle Nest Golf Course, Well HO-286, Peedee Aquifer System*	Myrtle Beach Air Force Base, Well HO-350, Bldg. 514, Water Table System, Upper Tertiary/Lower Quaternary**	Myrtle Beach Air Force Base, Low Fluoride Well, Bldg. 690, Water-Table Aquifer System***
Well Data				
Latitude (deg/min/sec)	33 39 38	33 53 25	33 40 54	33 39 25
Longitude (deg/min/sec)	78 56 53	78 36 40	78 56 38	78 56 18
Depth (feet)	760	132	42	32
Screened Interval (feet)	512 - 756	unknown	32-42	unknown
Groundwater Quality				
pH (std. units)	8.6	7.8	6.9	7.0
Specific Conductance (umhos/cm)	1,071	430	324	218
Dissolved Solids	531	276	224	132
Hardness (as $CaCO_3$)	12	270	140	-
Alkalinity (as $CaCO_3$)	551	221	148	-
Bicarbonate (HCO_3)	563	270	180	93
Fluoride (F)	2.8	0	0.2	0.1
Chloride (Cl)	79	14	18	20
Sulfate (SO_4)	1.3	2.8	0.4	2
Sodium (Na)	280	8.3	15	12
Potassium (K)	3.7	0.6	1.5	0.4
Calcium (Ca)	5.0	100	51	30
Magnesium (Mg)	0.5	4.0	3.1	1.6
Iron (Fe) (dissolved)	<0.4	6.1	10	2.7
Manganese (Mn)	-	0	0.1	-
Silica (SiO_2)	14	7.3	33	13

* From Zack, 1980, pgs. 9 and 14
**From Zack, 1977, pgs. 54,55,90, and 92
***From Draft Environmental Impact Statement, Grand Strand Region, South Carolina; EPA, 1977, pgs. 2-21

Almost all of the higher capacity wells (i.e., 100,000 gpd or more) and many low capacity wells in the Myrtle Beach area are completed into the Black Creek aquifer (Spigner, 1977). These wells are screened primarily in sand-rich zones that are situated throughout a 300 to 800-foot-depth interval. There are at least six wells within MBAFB, and at least 12 wells located adjacent to base boundaries, that are believed to be completed into the Black Creek aquifer system. Approximate locations of these wells are indicated on Figure 5; other available well information is presented in Appendix B. Additional private domestic wells may also tap the Black Creek aquifer in the vicinity of MBAFB; however, since they are not Class A public supply wells (which require groundwater use permits), their locations and depths have not been well documented.

The Peedee aquifer system is characterized by variable groundwater quality. Although chloride, sodium, and fluoride levels within this aquifer generally are substantially lower than that of Black Creek, the Peedee aquifer commonly contains undesirably high concentrations of iron, calcium, magnesium, and hydrogen sulfide and sulfate; high levels of these constituents could necessitate water treatment for certain uses (Zack, 1977). Consequently, development of the

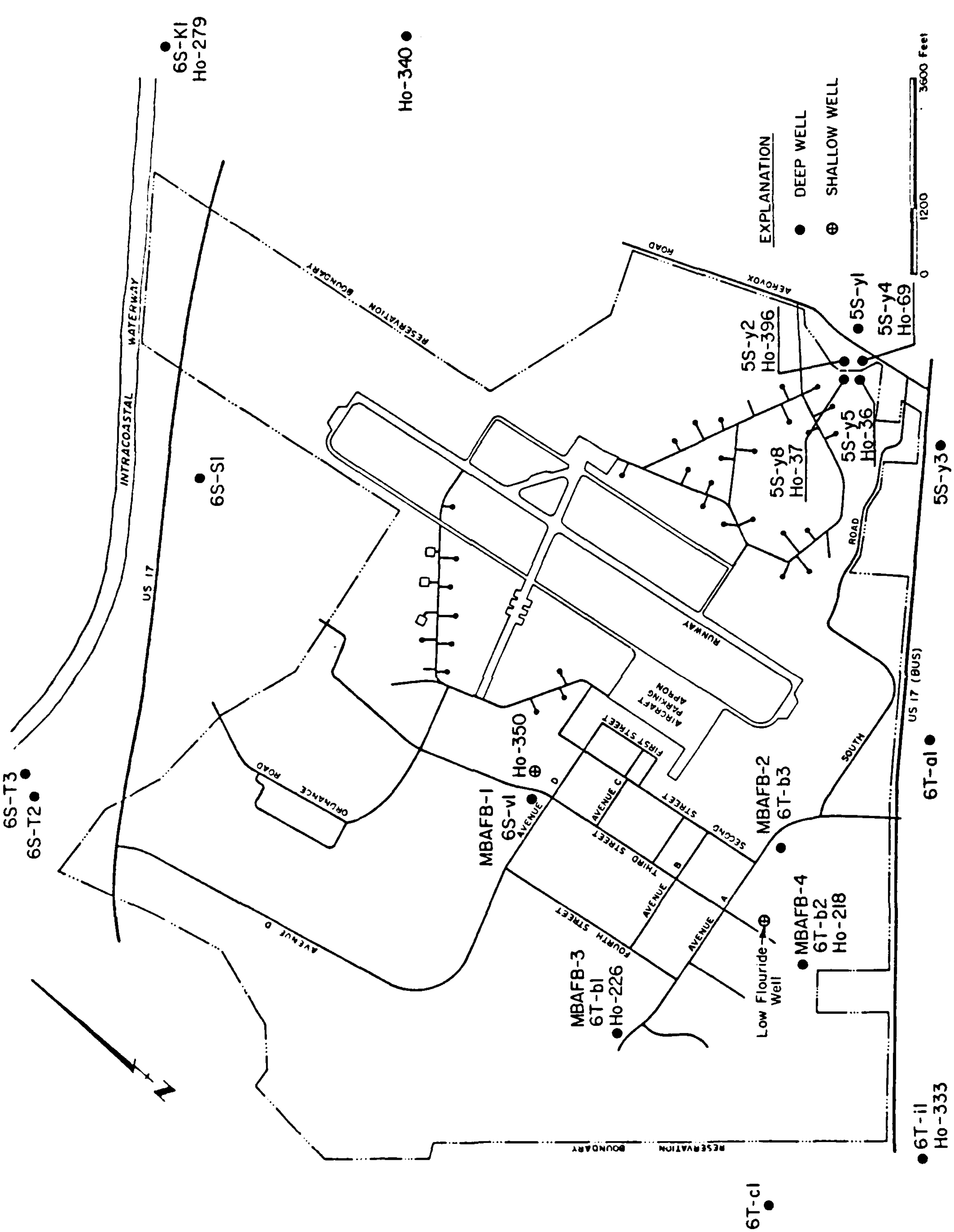


Figure 5. Approximate Locations of Water Wells Within and Adjacent to Myrtle Beach Air Force Base, South Carolina

Peedee aquifer for domestic supplies tends to be localized, with more widespread use being primarily related to irrigation (Zack, 1977).

Large capacity wells have generally not been developed into the Peedee aquifer system; but, it is suspected that this aquifer could probably supply as much water as the Black Creek aquifer (Spigner, 1977). Because few, if any, Class A wells have been developed into the Peedee, well inventory data is extremely limited, and it is uncertain whether or not wells have been completed into the Peedee aquifer in the vicinity of MBAFB.

The water-table aquifer system, for the purposes of this report, is considered to consist of shallow Tertiary and younger deposits, and commonly includes shallow artesian or semi-confined units. Groundwater within this system, particularly within shallow artesian units comprised of Tertiary sands, may be of very good quality (Zack, 1977). Information pertaining to the development of these aquifers is quite limited, but it is probable that many domestic wells throughout the area tap shallow artesian aquifers (100 feet or less in depth) for relatively large quantities of highly acceptable water (Zack, 1977). In general, this groundwater is characterized by 100 mg/l or less of hardness, low concentrations of fluoride and chloride, and negligible concentrations of iron, sulfate, and hydrogen sulfide (Zack, 1977). It should be noted, however, that in the vicinity of MBAFB, Tertiary deposits may not be sufficiently extensive to have warranted extensive development (see Figure 3).

In areas where confining layers are thin or absent, Tertiary deposits merge with the overlying surficial aquifer, which is probably comprised of the Waccamaw Formation and younger sediments. This condition generally decreases the quality of groundwater within the Tertiary system because the surficial aquifer commonly contains high concentrations of iron, and objectionable levels of various other parameters (Zack, 1977). Also, groundwater quality within the surficial aquifer is more susceptible to degradation from surface water bodies, or by extraneous substances that are leached from the land surface.

At least one drinking water well within MBAFB, the low fluoride well, is completed into the water-table aquifer system (see Figure 5). The quality of water from this well is listed in Table 4.

Historic and Potential Groundwater Problems

According to Zack (1977), one groundwater problem that is known to occur in the Myrtle Beach area relates to seasonal water-level declines within the Black Creek aquifer system. During summer months, when the population of this area is substantially greater, increased groundwater withdrawals have created drawdowns within the main aquifer which have caused some wells (especially the more shallow ones) to "go dry". This problem is often misconceived to be a result of diminishing groundwater supplies within Black Creek aquifer, but is more likely caused by improper well design and well spacing, i.e., wells are too closely spaced and do not efficiently utilize the full producing capacity of the aquifer. This has resulted in localized overdevelopment of the Black Creek aquifer, particularly within the upper sand units. The problem could be largely alleviated through proper design and spacing of well fields and utilization of other sands for future water supplies (i.e., more efficient groundwater management practices).

Another, somewhat more obscure, problem relates to contamination of freshwater wells and aquifers by salty water. Although this condition is often attributed to salt water encroachment or intrusion, the problem probably results from gravel-filter well construction and/or inadvertent screening of sands containing poor-quality water (Zack, 1977). Salty water entering wells through improperly placed screened sections not only degrades the quality of groundwater being pumped, but can migrate through the well into freshwater sand units when pumping is discontinued or when the well is abandoned (i.e., freshwater units of lower hydraulic potential). Gravel-filter wells pose essentially the same problems, except that salty or poor quality water moves across confining units via the relatively permeable gravel pack.

According to Zack (1977), there are many unplugged abandoned wells in Horry County that continually seep salty water into freshwater sands of the Black Creek aquifer system. Because this seepage will continue until hydraulic potentials equalize across all of the sands in the vicinity of the well, the longevity of the groundwater resource could be threatened if abandoned wells are not located and properly plugged.

Because most of the wells completed into the shallow aquifer systems (i.e., upper Peedee, Tertiary, and water-table systems) have not been recorded with State agencies, and can be replaced at a relatively low cost, limited information is available regarding groundwater problems within the shallow aquifers (aside from naturally poor water quality). Glowacz (1980) indicates that an unlined sewage treatment lagoon at Myrtle Beach State Park (adjacent to Highway Rt. 17 and MBAFB) has caused some groundwater degradation, as reflected by above-background levels of chloride, ammonia, sodium, total organic carbon, and total Kjeldahl nitrogen.

Because the water-table aquifer in the Myrtle Beach area lies within a few feet of the land surface, one could reasonably speculate that similar types of shallow ground-water contamination probably occur throughout numerous localized areas, primarily as a result of infiltration-type septic systems and privys. Also, in areas where soluble or mobile substances are stored or disposed of on the land surface, leachate could, and probably does, infiltrate to the shallow water-table system.

DESCRIPTION OF FIELD PROGRAM

INTRODUCTION

In an effort to specifically define hydrogeologic conditions beneath the potential contaminant source areas identified at the Myrtle Beach Air Force Base (MBAFB), Geraghty & Miller, Inc., in conjunction with RTI, implemented a drilling, soil-sampling, and groundwater monitoring program. The first phase of this program, referred to as the Basic Plan, was conducted during November and December, 1982. This work included an initial field reconnaissance of the identified sites, and the subsequent installation of borings, monitor wells, and well points. In addition, surface geophysical surveys were conducted in the Flight Line Area and the POL and Pipeline Spill Areas.

As a result of the Basic Plan efforts, shallow groundwater flow patterns were generally defined and two sets of selected groundwater samples were collected and analyzed for key water-quality parameters (see 12/82 and 02/83 Data Sets; Appendix G). These data were then inspected for important hydrogeologic trends, and a supplemental field program, referred to as Option I, was designed and implemented (during June 1983) to provide the additional information needed to fill data gaps. Option I work involved the installation of additional wells and well points, and the collection and analyses of a third (and final) set of groundwater samples (see 06/83 Data Sets, Appendix G).

In all, the combined Basic Plan and Option I field programs resulted in the installation of a total of 12 well points, 21 shallow soil borings (non-cased), and 44 borings that were converted to monitor wells. Borings and monitoring facilities installed at each of the potential contaminant source areas are listed in Table 5. Approximate locations of borings, wells, and well points are indicated on Figure 6 through 12; descriptions of materials encountered during drilling are presented in Appendix C. Details of the field work activities that were performed are presented in the following discussions.

TABLE 5.
BORINGS, SHALLOW MONITOR WELLS, DEEP MONITOR WELLS, AND WELL POINTS INSTALLED DURING THE BASIC PLAN AND OPTION I FIELD PROGRAMS CONDUCTED AT MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA

Potential Contaminant Source Area	Uncased Soil Borings (about 10 ft deep)	Soil Boring/ Monitor Wells (12 to 15 ft deep)	Soil Boring/ Monitor Wells (30 to 35 ft deep)	Well Points (4 to 5 ft deep)
Fire Training Areas #1 and #2	B-1, B-2, B-3, B-4, B-5	GM-1, GM-2, GM-3, GM-4, GM-5, GM-7, GM-8	GM-6, GM-9	none
Landfill #3/ Weathering Pit #2	B-6, B-7, B-8	GM-10, GM-11, GM-13, GM-14, GM-15,	GM-12, GM-16 GM-41	GM-17, GM-18, GM-51 GM-52, GM-53, GM-54, GM-55, GM-56
Fire Training Area #3	B-9, B-10	GM-19, GM-20, GM-21	GM-22, GM-42	none
Weathering Pit #1	B-11, B-12, B-13, B-14, B-15	GM-23, GM-24, GM-25 GM-26	GM-27, GM-43	GM-47, GM-48, GM-49, GM-50
Landfills #1 and #4	B-16, B-17, B-18, B-19 B-20	GM-29, GM-31, GM-32 GM-46	GM-28, GM-30 GM-45	none
POL Area	B-21	GM-33, GM-34, GM-35 GM-36	GM-44	none
Flight Line Area	none	GM-37, GM-38, GM-39 GM-40	none	none

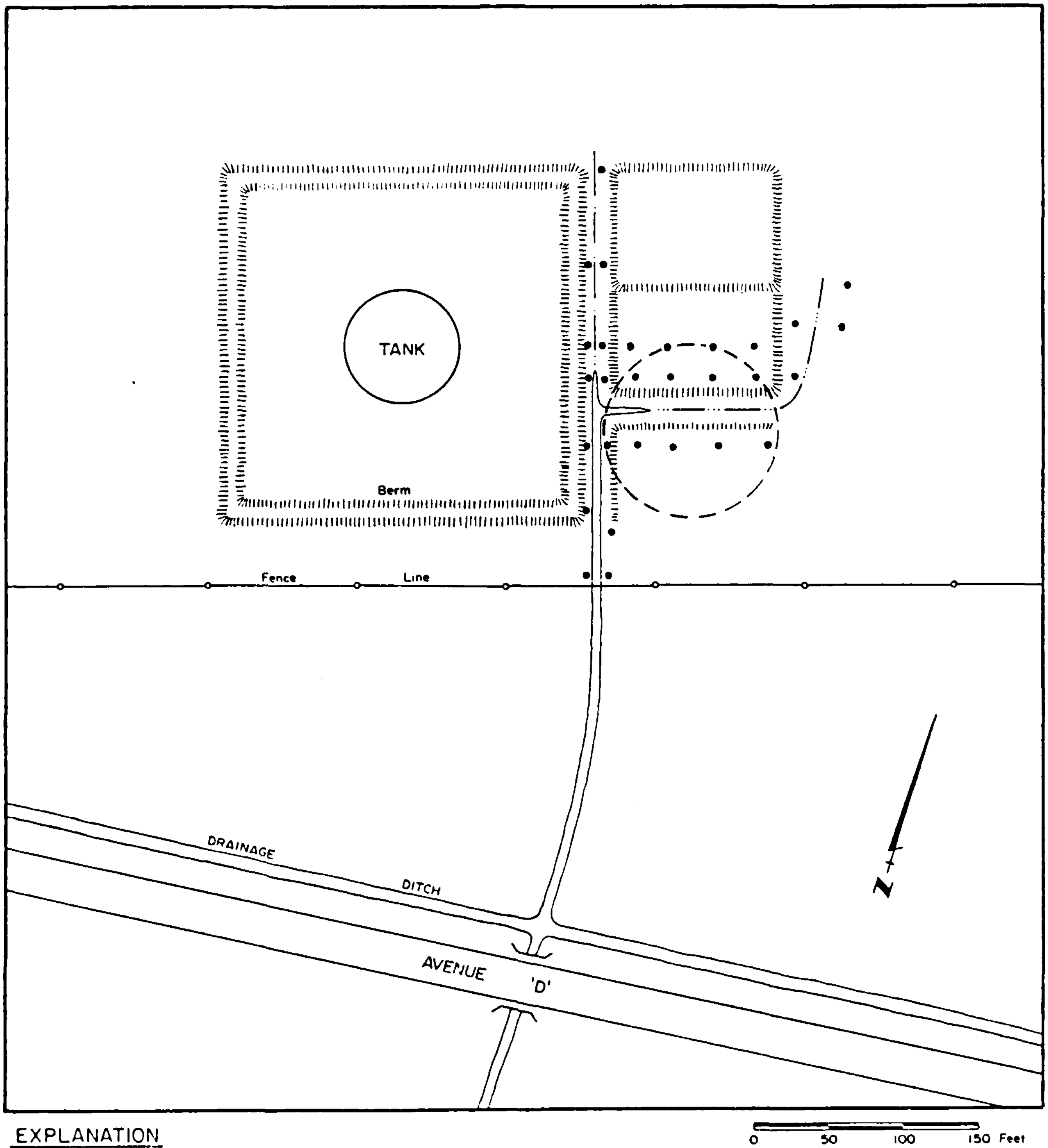
Note: All GM wells and well points with identification numbers above 40 were installed during the Option I program.

DRILLING AND SOIL SAMPLING PROGRAM

Following a review of the preliminary reconnaissance data, Geraghty & Miller, Inc., implemented a drilling and soil-sampling program to determine site geologic conditions and to establish a system of groundwater monitoring wells. Geotechnical activities at most of the sites began with the installation of shallow borings (designated as B-1, B-2, etc.) that were drilled and sampled to depths of about 10 feet. Upon completion, these borings were backfilled with formation cuttings and abandoned.

Geologic and OVA data obtained from the shallow borings were then evaluated along with other preliminary data, and locations for monitor well installations were selected. Efforts were made to situate most of the monitor wells next to, and/or hydraulically downgradient from, the suspected contaminant source areas; at least one monitor well was also located hydraulically upgradient of each site in order to assess the quality of relatively unaffected groundwater.

Most of the monitor wells (referred to as shallow wells) were installed to depths of 12 to 15 feet below ground level, into the shallow water table. With the

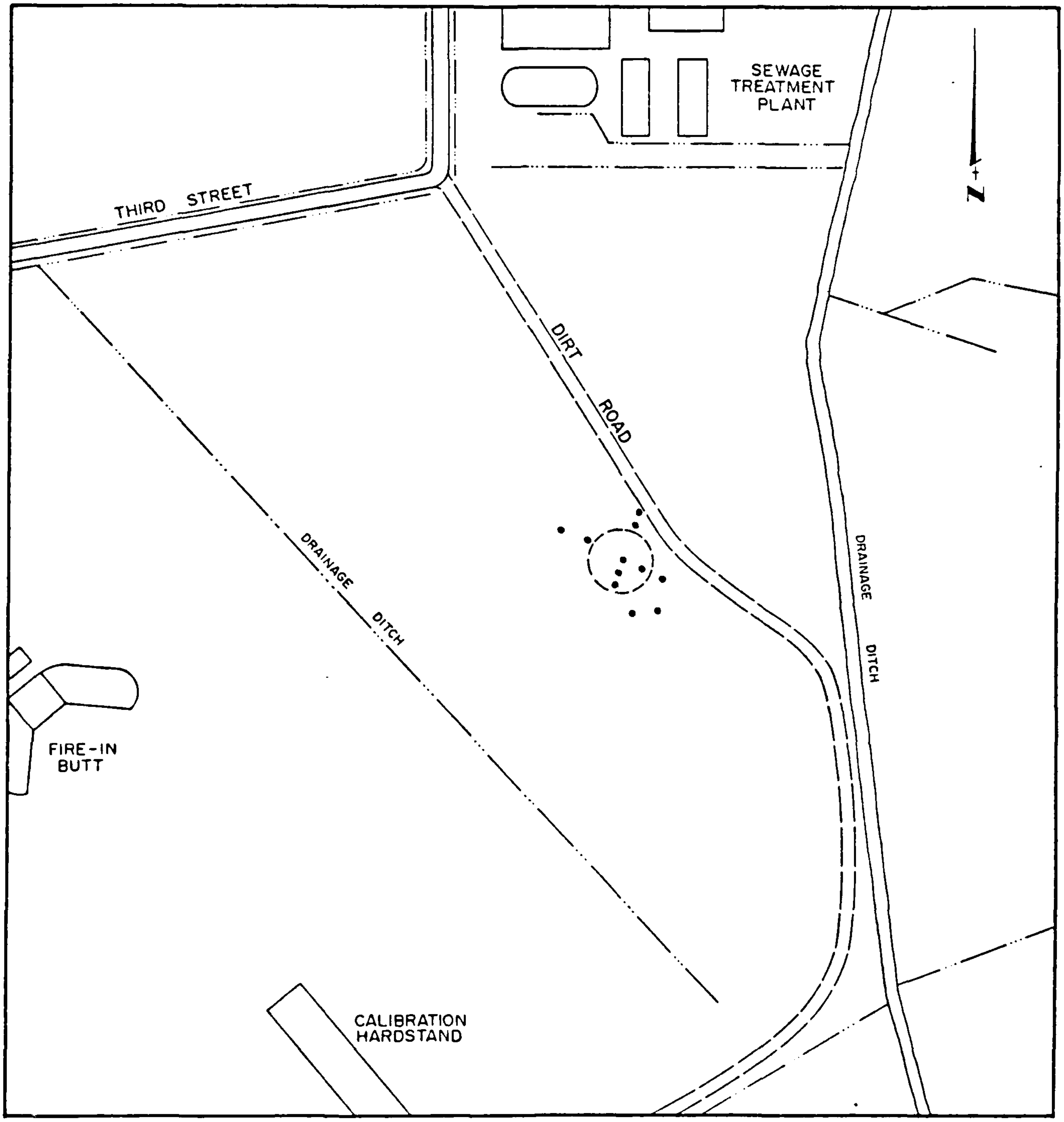


EXPLANATION

● HAND AUGERED BORING

----- PRINCIPAL AREA OF CONCERN

Figure 15. Approximate Locations of Hand Auger/OVA Inspections at POL Area, Myrtle Beach Air Force Base, South Carolina



EXPLANATION

• HAND AUGERED BORING

------ PRINCIPAL AREA OF CONCERN

Figure 14. Approximate Locations of Hand Auger/OVA Inspections at Fire Training Area #3, Myrtle Beach Air Force Base, South Carolina

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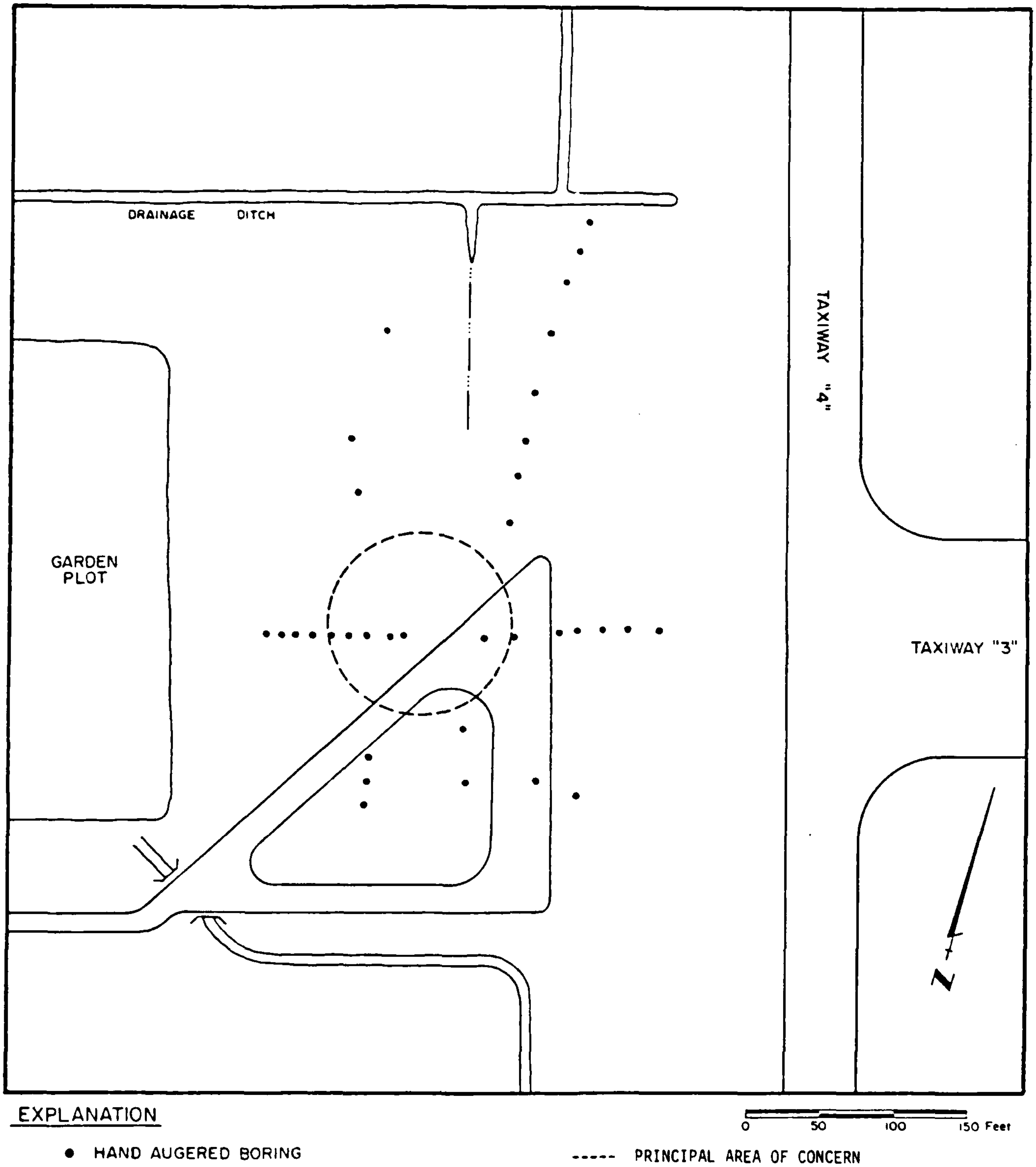

Figure 13. Approximate Locations of Hand Auger/OVA Inspections at Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina

feet below land surface (generally down to the water table), and the OVA was used to detect the presence of volatile organic compounds that collected within the borehole; approximate locations of hand-auger/OVA inspections are indicated on Figures 13 through 15. It should be noted that the OVA served simply as an indicator for the presence/absence of potential volatile hydrocarbons and that quantification with the device is not justified. Nevertheless, OVA readings were used to assist in estimation of an apparent extent of potential contaminant migration, and thus aided in placement of monitor wells.

Pipeline Spill Area. This second phase of work, which was considerably more detailed than initial efforts, resulted in the mapping of a high-conductivity plume that apparently emanates from the area where the spill occurred; see Appendix D, Part 2.

Initial Site Reconnaissance

At the beginning of the Basic Plan field program, preliminary site inspections were conducted at each of the potential source areas in order to roughly delineate site boundaries, and to identify important surface features (e.g., drainage ditches) that could influence shallow groundwater flow patterns. Because activities at several of the identified areas were discontinued years ago, site boundaries were sometimes obscured by trees, grass, and underbrush. This problem was largely resolved through use of old aerial photographs and contacts with Air Force personnel who were previously involved with activities conducted at the various sites.

In an effort to further define site boundaries, traverses were made of the Fire Training Areas (#1, #2, and #3) and the POL Spill Area, using a hand auger and an organic vapor analyzer (OVA). In this procedure, hand-augered borings were installed to depths of four to five

PRELIMINARY MEASURES

Surface Geophysical Surveys

Based on recommendations contained in the Phase I IRP conducted by Engineering-Science (1981), initial surveys using surface geophysical testing methods (ground conductivity measurements) were carried out in the POL, Flight Line, and the Pipeline Spill Areas. This work was performed by Earth Tech Research Corporation using a non-contacting terrain conductivity meter, and involved traversing the sites to detect conductivity anomalies that could be interpreted to delineate contaminant plumes. At each site, coils of the conductivity meter were oriented both vertically and horizontally, corresponding to penetration depths of about 15 feet and 5 feet, respectively.

No significant anomalies in electrical conductivity were observed in the Flight Line and POL areas, suggesting that conductive plumes of contamination were not present within shallow sediments beneath these sites. However, a very significant conductivity anomaly was observed in the Pipeline Spill Area; (see Appendix D, Part 1).

Based on results of the initial conductivity survey, a second geophysical testing program was conducted in the

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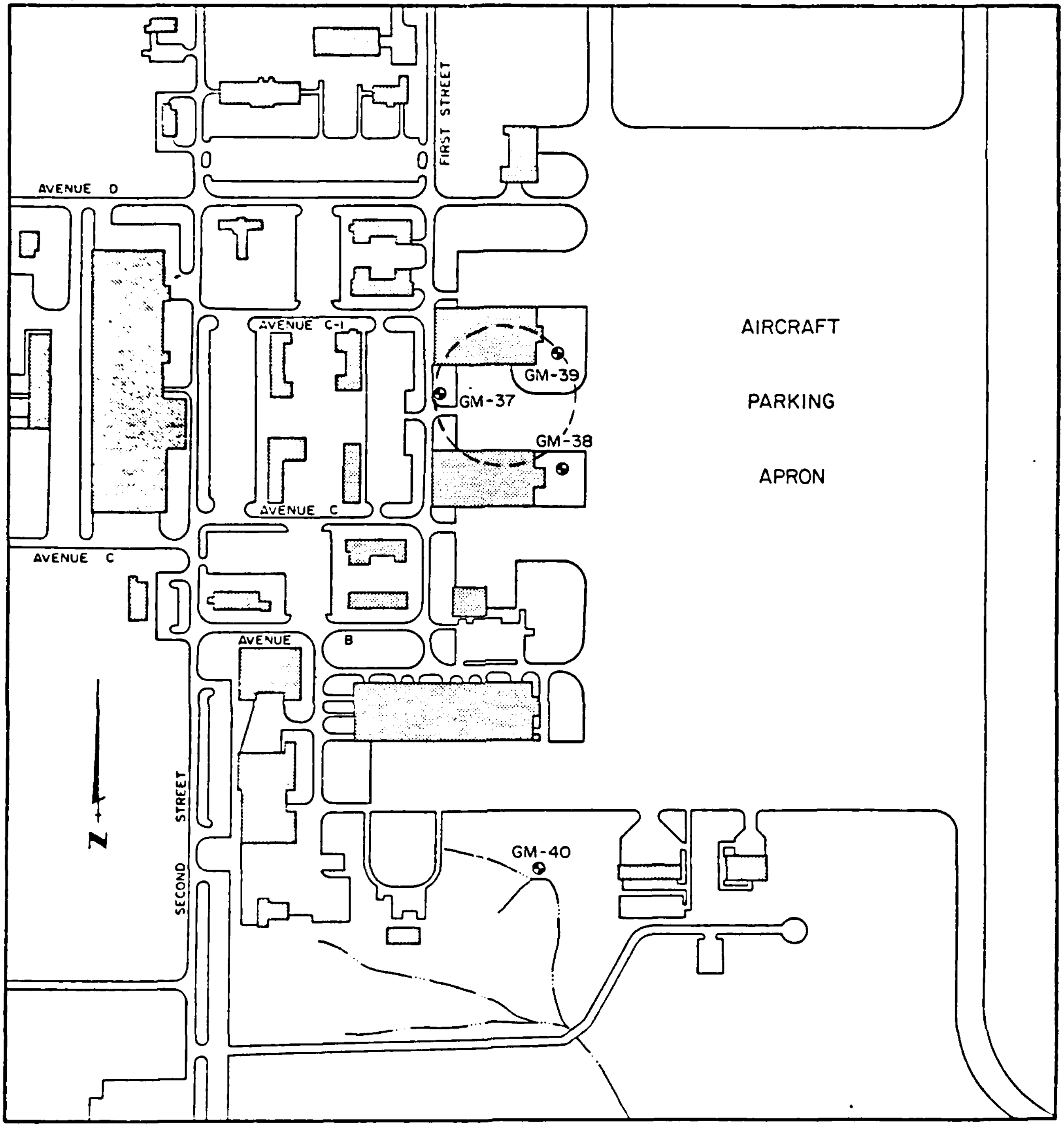

EXPLANATION

0 200 400 Feet

⊕ GM-38 LOCATION OF SHALLOW MONITOR WELL

----- PRINCIPAL AREA OF CONCERN

Figure 12. Locations of Soil Borings and Monitor Wells at the Flight Line Area, Myrtle Beach Air Force Base, South Carolina

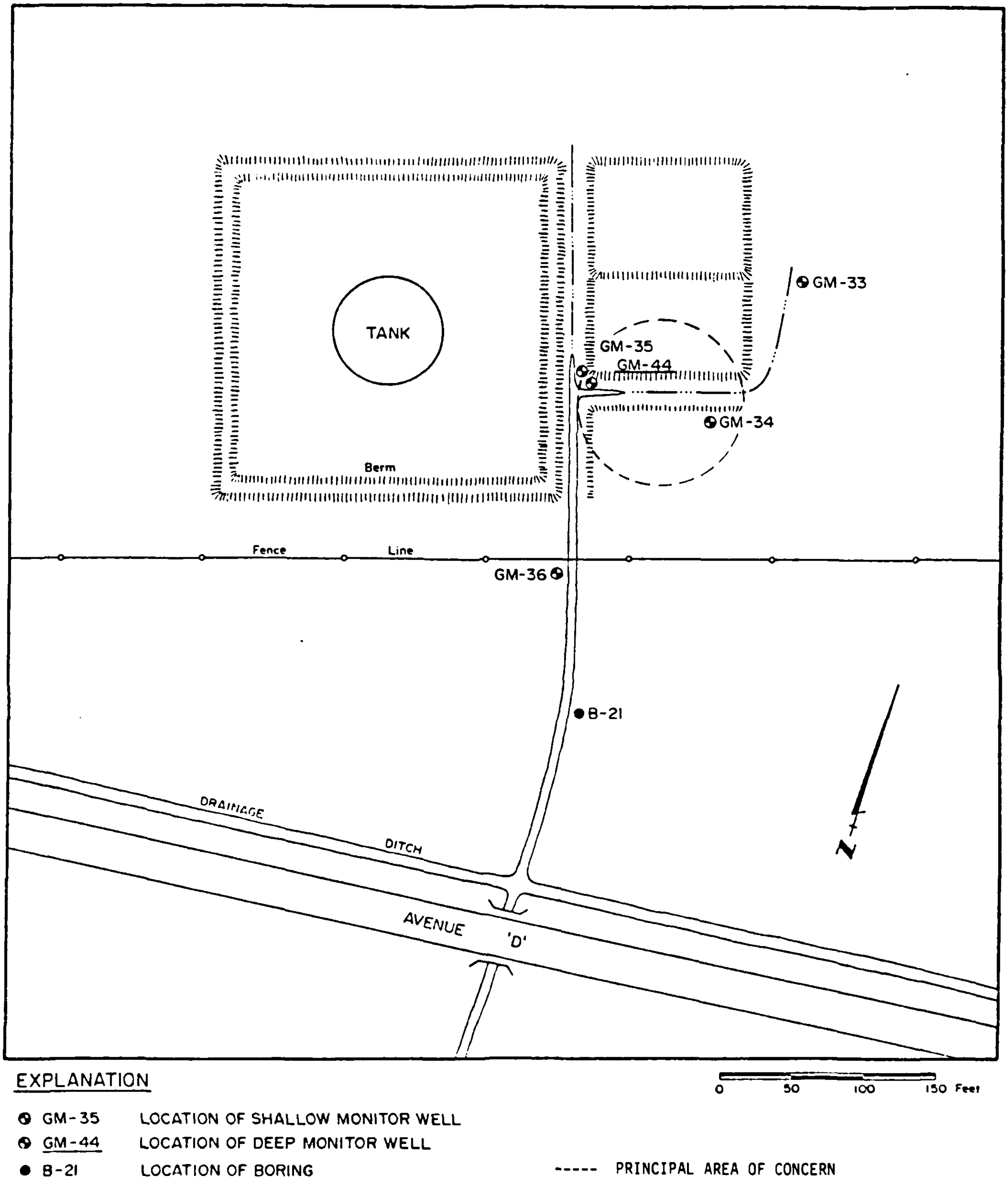

Figure 11. Locations of Soil Borings and Monitor Wells at the POL Area, Myrtle Beach Air Force Base, South Carolina

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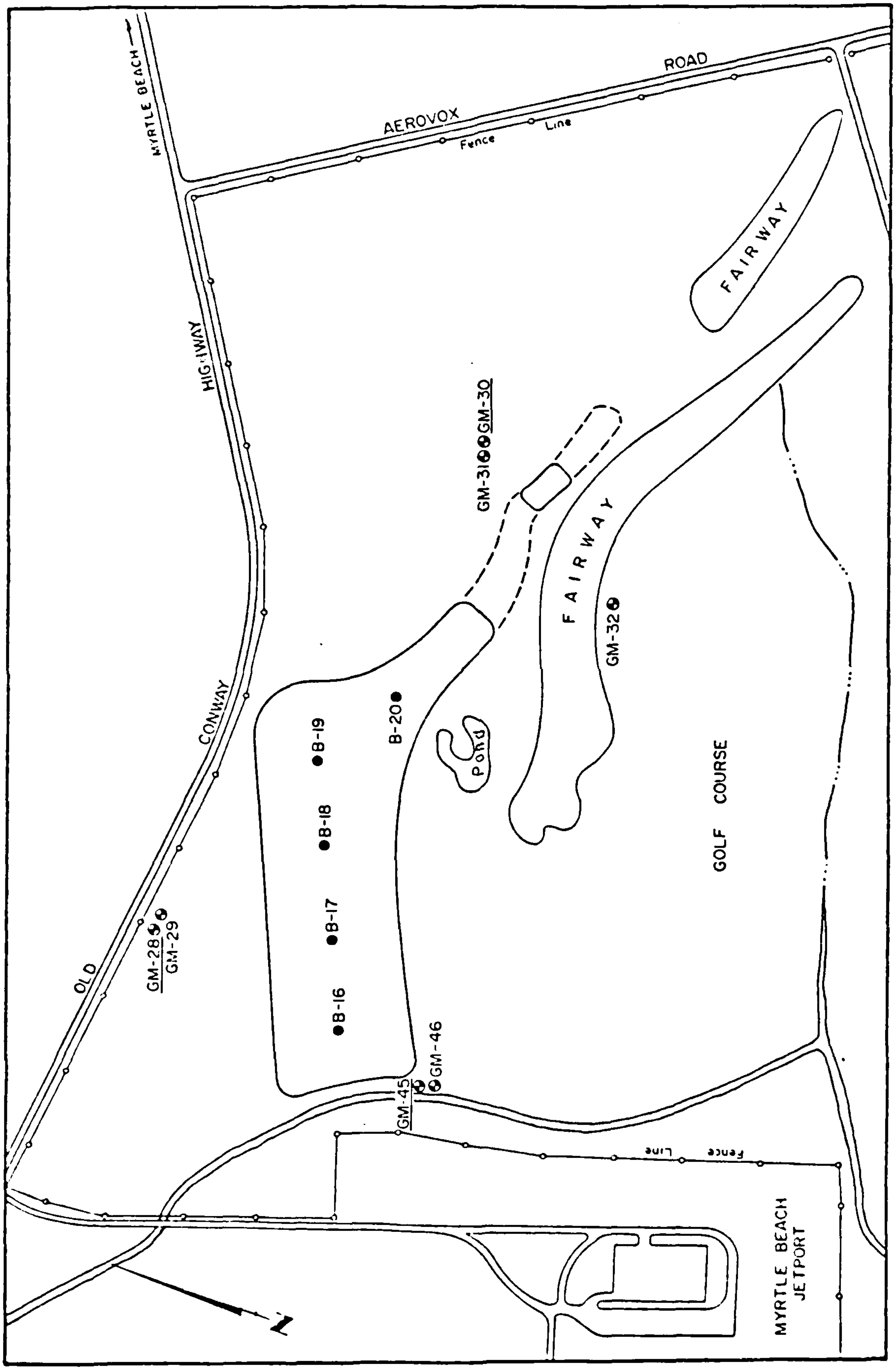
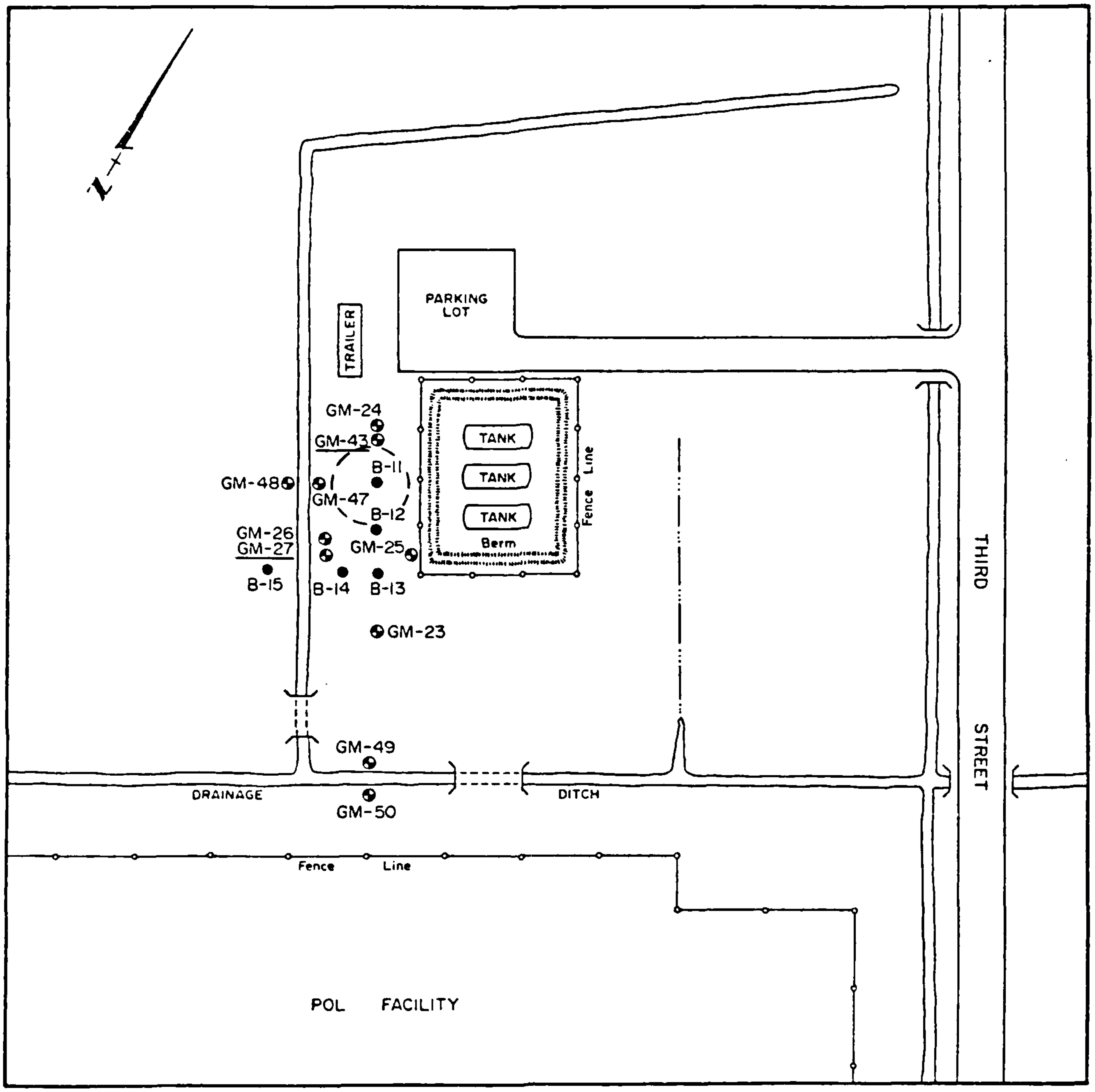


EXPLANATION

- GM-29 LOCATION OF SHALLOW MONITOR WELL
- GM-28 LOCATION OF DEEP MONITOR WELL
- B-17 LOCATION OF BORING

Figure 10. Locations of Soil Borings and Monitor Wells at Landfills #1 and #4, Myrtle Beach Air Force Base, South Carolina



EXPLANATION

GM-24	LOCATION OF SHALLOW MONITOR WELL
GM-27	LOCATION OF DEEP MONITOR WELL
B-11	LOCATION OF BORING
-----	PRINCIPAL AREA OF CONCERN

Figure 9. Locations of Soil Borings and Monitor Wells at Weathering Pit #1, Myrtle Beach Air Force Base, South Carolina

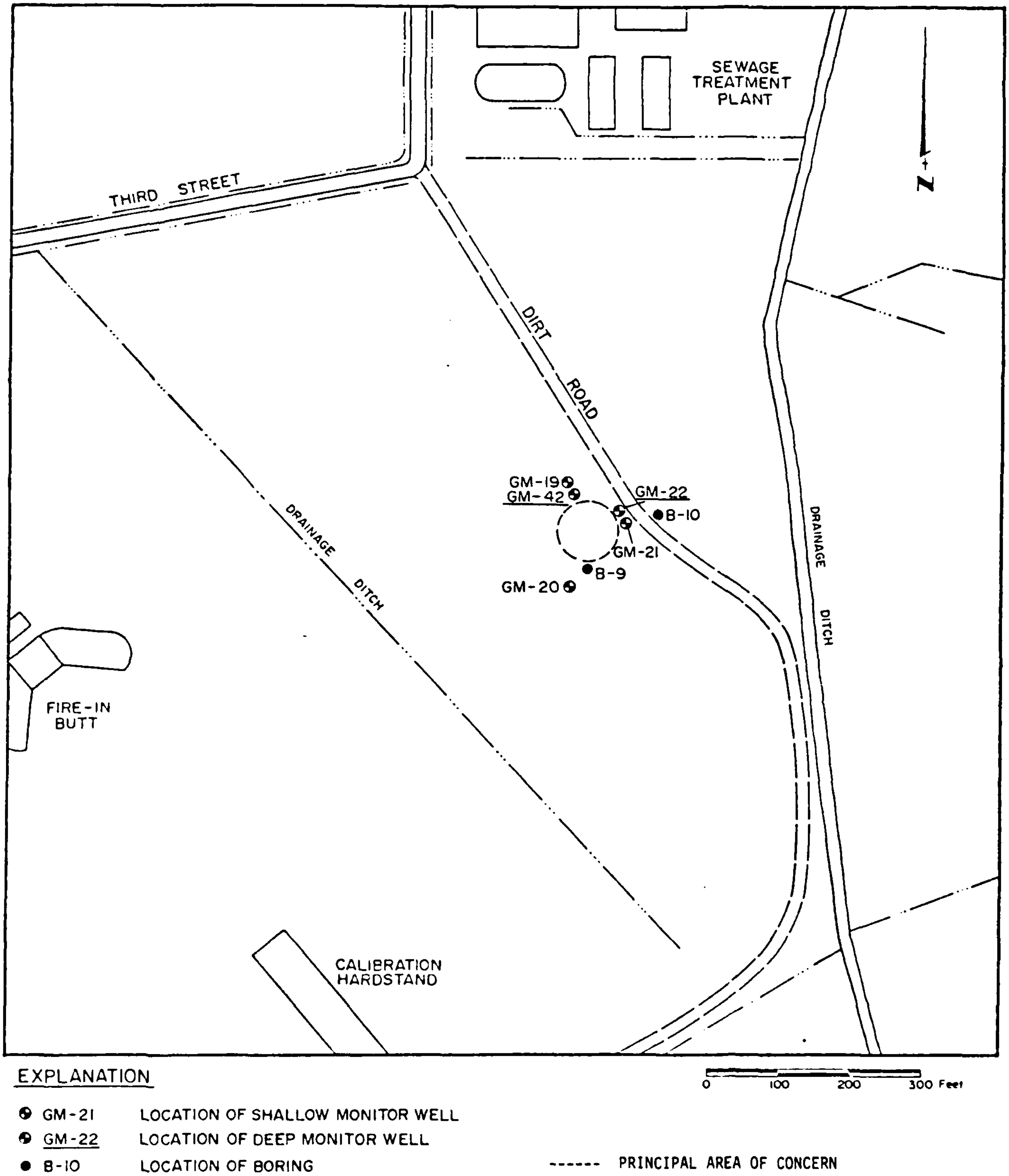
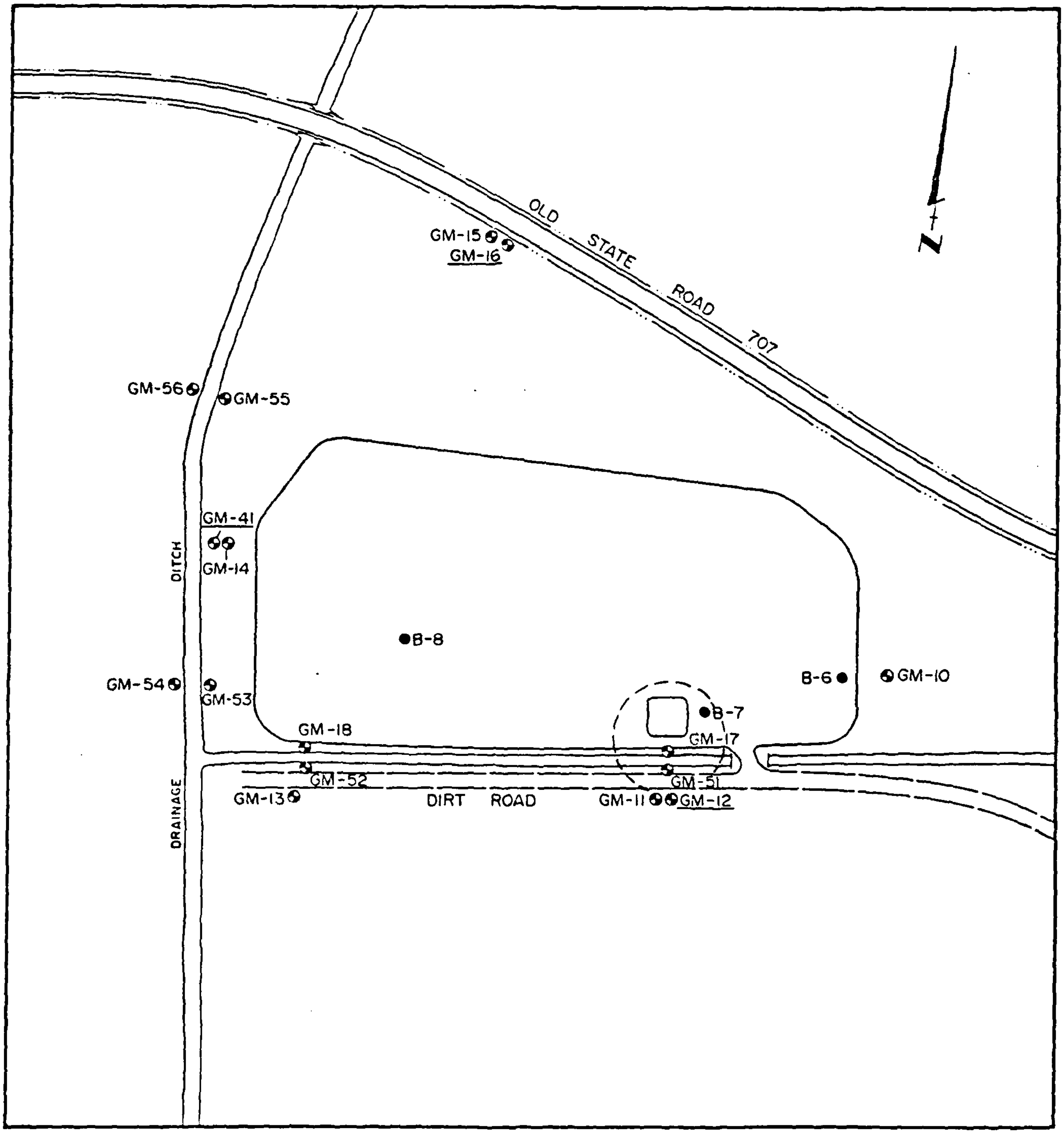


Figure 8. Locations of Soil Borings and Monitor Wells at Fire Training Area #3, Myrtle Beach Air Force Base, South Carolina

Geraghty & Miller, Inc.

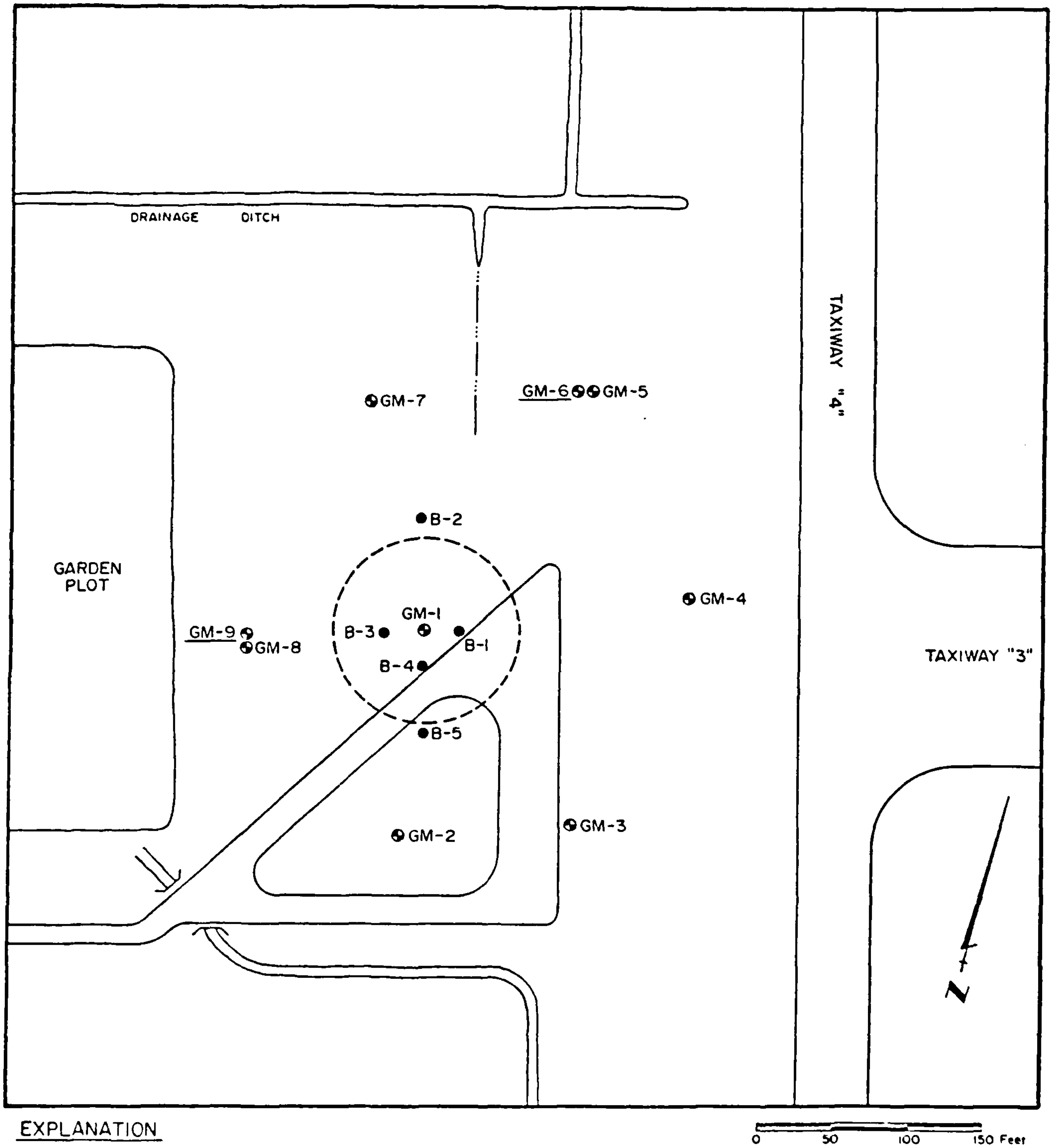


EXPLANATION

0 100 200 300 Feet

- GM-15 LOCATION OF SHALLOW MONITOR WELL
- GM-16 LOCATION OF DEEP MONITOR WELL
- B-8 LOCATION OF BORING
- ----- PRINCIPAL AREA OF CONCERN

Figure 7. Locations of Soil Borings and Monitor Wells at Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina



EXPLANATION

GM-5 LOCATION OF SHALLOW MONITOR WELL
GM-6 LOCATION OF DEEP MONITOR WELL
B-1 LOCATION OF BORING
------ PRINCIPAL AREA OF CONCERN

Figure 6. Locations of Soil Borings and Monitor Wells at Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina

exception of the Flight Line Area, one or more deep monitor wells (about 30 feet deep) were also installed at each site so as to document water-level and water-quality conditions within lower portions of the water table or within shallow artesian units. Each deep monitor well is paired with a shallow well so that hydraulic head relationships between upper and lower water-bearing zones can be determined.

At Weathering Pit #1 and Landfill #3/Weathering Pit #2, well points (4 to 5 feet deep) were also installed adjacent to, and on both sides of, main drainage ditches (i.e., well point pairs) in order to assess the extent to which ditches serve as interceptors of, and barriers to, lateral groundwater flow (and contaminant migration) within the shallow water table. A listing of monitoring facilities installed at each of the potential contaminant source areas is summarized in Table 5. Locations of well points, borings, and shallow and deep monitor wells, are shown on Figures 6 through 12.

Drilling, soil sampling, and monitor well installation and development, were done by A-C Borings, Inc., of St. Matthews, South Carolina, under the inspection of a Geraghty & Miller, Inc., representative. All well points were installed by Geraghty & Miller, Inc., personnel. The general procedures utilized in these programs are discussed below.

Boreholes were drilled to depths ranging from 10 to 35 feet using conventional 3-1/2-inch I.D. hollow-stem augers. Auger flights were washed prior to drilling to each location so as to avoid cross-contamination between boreholes. Drilling was completed without adding any fluid to the borehole.

Core samples were taken at 5-foot intervals, except when approaching the water table, where sampling was continuous. Samples were collected using a 24-inch-long, 2-inch-diameter split-spoon sampling device that was driven ahead of the lead-auger flight. Prior to collecting each core, the split-spoon sampler was thoroughly washed to avoid cross-contamination between soil samples. Immediately after the spoon was withdrawn from the boring, samples were collected in glass jars and sealed with aluminum foil. All cores were inspected and described in the field by a Geraghty & Miller, Inc., representative. At the end of each day of drilling, the OVA was used to measure volatile organics that accumulated in the head spaces of the sample jars. Lithologic descriptions and OVA values for materials encountered during drilling are presented in Appendix C.

MONITOR-WELL INSTALLATION AND DEVELOPMENT

With the exception of the 10-foot-deep soil borings (i.e., B-1 through B-21), all boreholes were converted to monitor wells to facilitate water-level measurements and groundwater sampling. The monitor-well assemblies, which consist of 2-inch-diameter PVC casing coupled to bottom sections of 2-inch-diameter, 0.008-inch-slot PVC well screen, were inserted through the inner bore of the hollow-stem auger flights. After the wells were in place, augers were pulled allowing the formation materials to collapse in around the well screen. After the last auger flight was pulled, enough sand was added to the borehole to bring the sand pack to within two feet of the surface. A 6-inch bentonite plug was then installed and the remaining annular space filled with cement. Protective steel well covers were placed over the monitor wells and seated into the cement. Deep monitor wells installed into the lower water-table and shallow artesian unit were also equipped with a grout plug to maintain the natural hydraulic separation between the (upper) water table and lower water-bearing units.

Well points were installed using a nominal 3-1/2-inch diameter hand auger. After the boring was drilled, a 2-inch diameter PVC well point assembly equipped with a

3-to-4-foot-long bottom section of 0.008-inch-slot PVC well screen was installed. The annulus was filled with sand to within six inches of land surface, and the remaining annular space was plugged with bentonite. Roughly two feet of PVC casing stands above ground level and each assembly is loosely fitted with a PVC cap. Figure 16 depicts typical monitor well and well point construction. Construction details for individual wells and well points are presented in Appendix E.

All wells were developed using a centrifugal pump for a period of one hour. Where well yields were low, wells were pumped dry and allowed to recover; and the procedure was repeated until wells were adequately developed. In addition, an amount of water equal to three well volumes of standing water was removed from each well prior to each sampling.

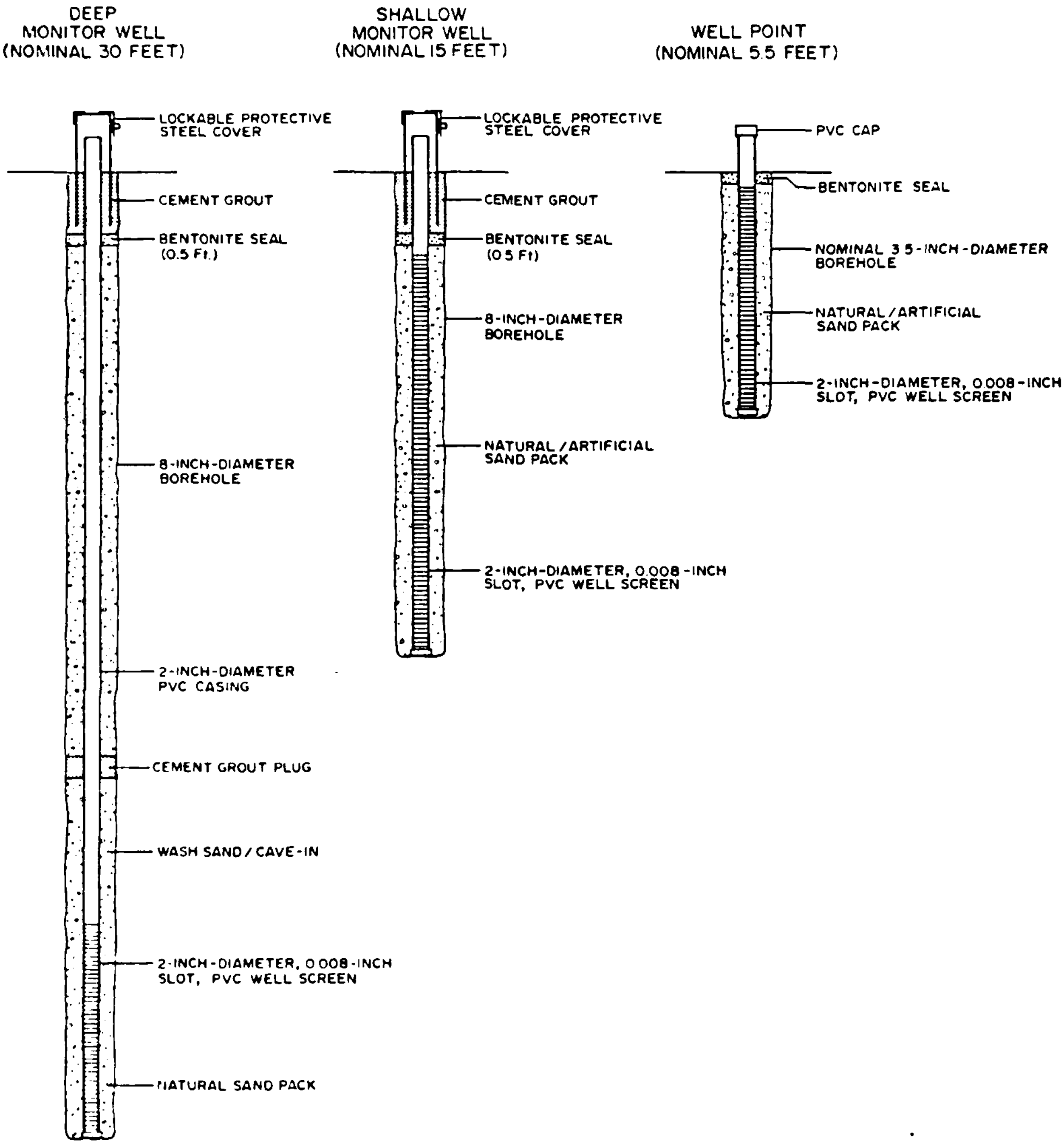


Figure 16. Typical Monitor Well and Well Point Construction at Myrtle Beach Air Force Base, South Carolina

WATER-QUALITY SAMPLING AND ANALYSIS

Following monitor well development, groundwater samples were collected for the purpose of water-quality analysis. Prior to sampling, water levels were measured in each well, followed by the evacuation of three well volumes of water. Samples were then drawn from the well through 1/4-inch polyethylene tubing attached to a peristaltic pump. The volume of sample collected at each location varied depending on what laboratory analyses were to be performed. Samples containing suspended particulate matter were filtered in the field using 0.45 micrometer (um) membrane filters and an in-line filtering apparatus. Samples were preserved with acid or base according to EPA specifications (EPA-600/4-79-020, Methods for Chemical Analysis of Water and Wastes).

Efforts were made to draw samples from within three inches of the top of the water column so as to collect lighter-than-water compounds that may have been more concentrated in this zone. Samples were then preserved in accordance with laboratory specifications and were kept chilled until delivery to the lab. Polyethylene tubing was left in each well for the next sampling period.

Field measurements for temperature, pH, and specific conductivity were also taken at the time of each sampling. Results of these analyses are presented in Appendix F.

To summarize, groundwater samples were collected and analyzed three times throughout the course of this study; the dates during which these programs were conducted are December 8, 9, and 10, 1982, February 18 and 19, 1983, and June 7 and 8, 1983. Results of laboratory analyses of groundwater samples are presented in Appendix G.

RESULTS AND FINDINGS

Geologic data provided by the drilling and soil-sampling programs (Appendix C) conducted at MBAFB indicate that the shallow geology beneath the northwestern part of the base differs significantly from the geology beneath southern and northeastern portions. Therefore, general hydrogeologic trends within these two areas will be discussed separately. General discussions will be followed by site-specific descriptions of geologic and hydrologic conditions beneath each of the identified potential contaminant source areas.

GENERAL HYDROGEOLOGY: MBAFB-NORTHWEST AREAS

The POL area, Landfill #3, the Pipeline Spill Area, and all of the Weathering Pits and Fire Training Areas that were investigated, are located in the northwestern part of MBAFB. This area is generally underlain (to drilling depths of 30 feet or more) by sand layers with varying amounts of silt and clay that alternate with clay layers containing varying amounts of sand and silt. Within the 30-foot depth that was studied, at least four layers were usually distinguishable. Each of the upper two or three layers range from a few feet to ten feet or more in thickness, with the surficial unit of the series being comprised of either predominantly sand or predominantly clay materials. Ground-water, representing the water table, was encountered within the upper one or two layers, at depths ranging from less than five to ten feet below the land surface. Water-level data is presented in Appendix H.

A shallow artesian (confined to semi-confined) water-bearing unit is also usually present beneath northwestern areas of the base. This unit was commonly encountered within the lowermost, predominantly-sand layer, at depths ranging from 20 to 35 feet. The sand layer is overlain by a 7- to 20-foot-thick layer of predominantly clay materials, which appears to act as the confining unit. Results of falling-head permeability analyses indicate that the clays are characterized by fairly low vertical permeabilities (Kv) of roughly 10^{-7} cm/sec (see Table 6).

Vertical hydraulic head relationships between the water-table and the shallow artesian unit (Table 7) were usually found to be positive, i.e., a potential exists for downward flow of groundwater from the water table to the underlying unit. However, during a relatively dry period of the summer (corresponding to the 06/06/83 monitoring event) vertical hydraulic gradients beneath far northern

TABLE 6.
RESULTS OF SOIL TESTS AND FALLING-HEAD PERMEABILITY ANALYSES OF SELECTED CLAY-RICH SAMPLES FROM MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA

Boring Number	Sample Depth Interval (ft)	Natural Moisture Content (%)	Dry Density (PCF)	Vertical Permeability, K (cm/sec)
GM-41	12.5-14.5	97.2	46.7	1.04×10^{-7}
GM-42	15.0-17.0	145.0	47.7	4.65×10^{-8}
GM-43	20.0-22.0	30.5	75.3	1.31×10^{-7}
GM-44	15.0-17.0	76.4	60.7	7.58×10^{-8}

PCF-Pounds per cubic foot

TABLE 7.
HYDRAULIC HEAD RELATIONSHIPS BETWEEN THE UPPER WATER-TABLE AND UNDERLYING WATER-BEARING SEDIMENTS AT MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA
(All gradients expressed in Feet)

Well Pair	General Location	Vertical Hydraulic Gradient (I_v) (12/07/82)	Vertical Hydraulic Gradient (I_v) (02/14/83)	Vertical Hydraulic Gradient (I_v) (06/06/83)
GM-5/GM-6	FTA #1,#2	3.30	3.43	3.64
GM-8/GM-9	FTA #1,#2	4.10	4.71	3.90
GM-11/GM-12	LF#3, WP#2	0.28	1.05	0.06
GM-14/GM-41	LF#3, WP#2	-	-	-0.99
GM-15/GM-16	LF#3, WP#2	1.50	1.69	-1.49
GM-19/GM-42	FTA#3	-	-	-0.48
GM-21/GM-22	FTA#3	1.90	3.24	-0.48
GM-24/GM-43	WP#1	-	-	3.13
GM-26/GM-27	WP#1	4.45	4.40	3.02
GM-29/GM-28	LF#4	3.90	3.16	4.13
GM-31/GM-30	LF#1	4.62	4.43	5.06
GM-46/GM-45	LF#4	-	-	3.25
GM-35/GM-44	POL	-	-	2.91

General Locations:

FTA - Fire Training Area
LF - Landfill
WP - Weathering Pit
POL - POL

Note: GM-#/GM-# corresponds to shallow/deep monitor well; I_v = water level elevation in the shallow well minus water level elevation in the deep well.

parts of the base (near Landfill #3/Weathering Pit #2, and Fire Training Area #3) became reversed; i.e., favoring upward flow of groundwater to the water table. The change in head relationships suggests that the water table (at least in this part of the base) is relatively more susceptible to short-term, water-level declines than the shallow artesian unit. This, in part, could be caused by the greater abundance of forest-type vegetation in this area, which could significantly increase the loss of water-table fluids via evapotranspiration; or, the fact that drainage ditches in this area are relatively deep and, thus, may tend to more readily dewater shallow water-bearing sediments. Such conditions may also reflect an increased degree of hydraulic independence between the water table and shallow artesian units beneath this area.

Groundwater flow patterns within water-table sediments appear to be largely controlled by man-made drainage ditches (Figure 17). These features were primarily designed to direct surface runoff and overland flow to tributaries of major drainageways; but, also serve to dewater shallow deposits, thus, exerting an influence on local flow patterns. In general, the more deeply incised ditches impose the most obvious controls over groundwater flow. However, during wet seasons, when water levels rise to within a few

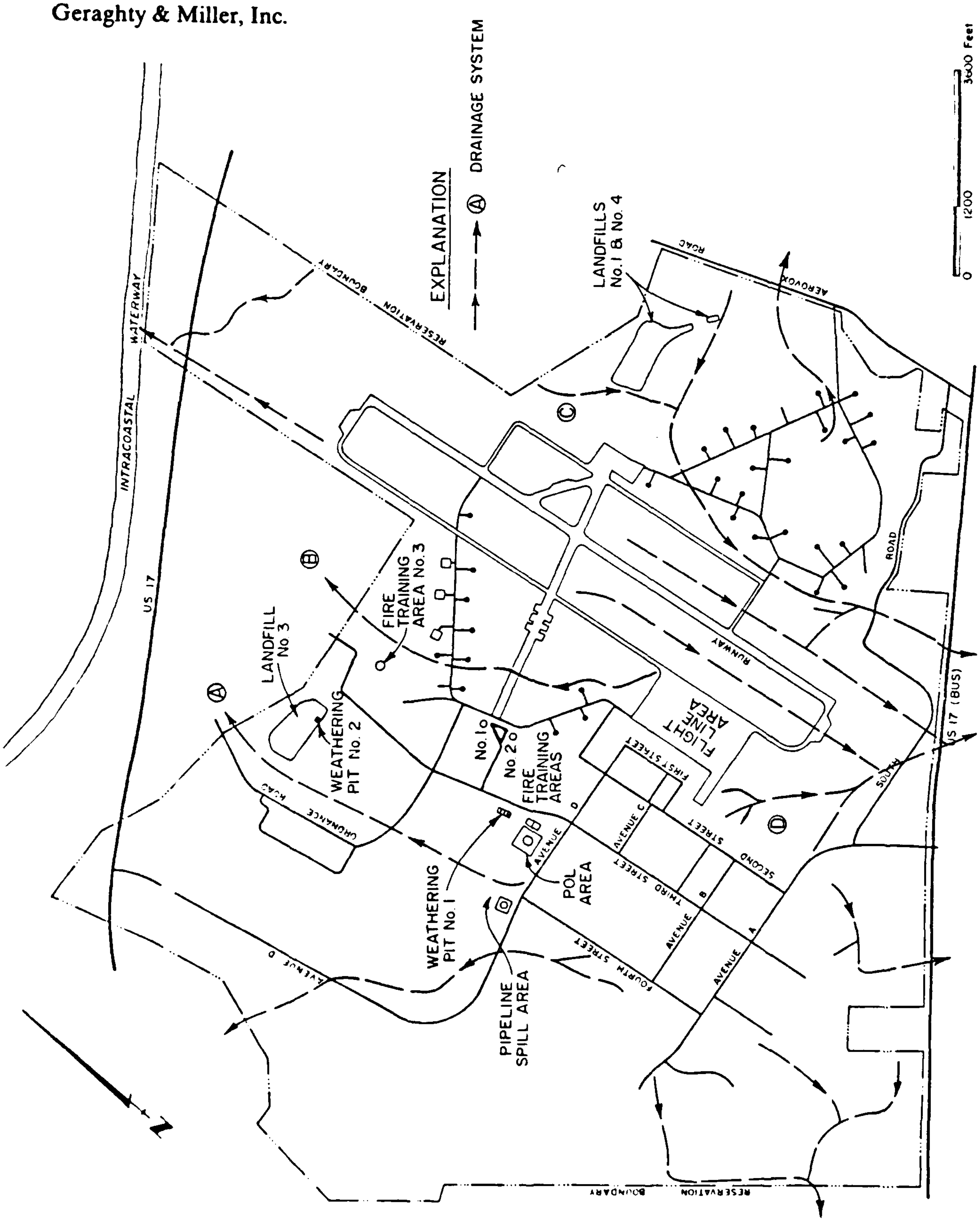


Figure 17. Identified Potential Source Areas and Important Drainage Ditch Systems at Myrtle Beach Air Force Base, South Carolina (Repeat of Figure 1)

feet of the land surface, even relatively shallow ditches can have an observable effect on the local configuration of the water table.

Surface-water drainage and shallow groundwater discharge from at least five, and possibly all, of the potential contaminant sources in the northwestern part of the base appear to be collected primarily by one main drainage system (see Drainage System "A", Figure 17). Drainage from the two Fire Training Areas (i.e., #3 and combined #1 and #2) may, under certain weather and water-level conditions, also discharge to a smaller drainage system located to the west of the main alignment (see Drainage System "B", Figure 17).

Available data are not adequate to describe groundwater flow conditions within the shallow artesian unit. At Landfill #3/Weathering Pit #2 (where three wells have been screened into this zone) observed water levels suggest that deep drainage ditches may also exert some influence over flow within the artesian unit; i.e., hydraulic gradients within the artesian unit appear to slope generally toward the main drainage ditch.

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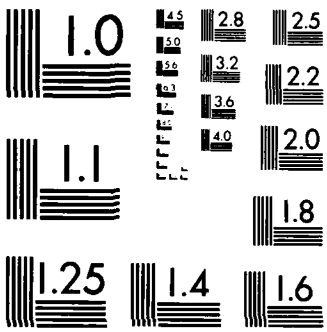

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GENERAL HYDROGEOLOGY:
MBAFB-NORTHEASTERN AND SOUTHERN AREAS

Landfills #1 and #4, and the Flight Line Area are located in eastern and southern parts of the base, respectively. These areas are underlain by thicker and more continuous deposits of sand than were present in northwestern areas. Data from the Landfill Area suggest that this sand could, in places, be underlain by clay, at depths of 25 feet or more. However, this trend is not consistent throughout, and there is not sufficient data to speculate as to the general nature of deposits beneath the sand.

The water table is also encountered within five to ten feet of the land surface in this part of the base. Owing to the general absence of confining clay layers, there do not appear to be any shallow artesian units within the deposits that were investigated (i.e., the upper 30 feet).

Shallow groundwater flow patterns, at least in the vicinity of the landfills, also appear to be controlled by drainage ditch systems (see Drainage System "C", Figure 17). Flow patterns beneath the Flight Line Area are more complex, possibly reflecting an influence by underground storm drain systems. Flow patterns in these areas will be discussed in the subsequent section describing site-specific conditions.

FIRE TRAINING AREAS #1 AND #2

Hydrogeology

Fire Training Areas #1 and #2 are located at the end of Taxiway "3", and are bordered by a large garden-plot area to the west, and level grassy fields on all other sides. Shallow sediments beneath this area are comprised of a 3- to 8-foot-thick surficial zone of predominantly sand materials, which is underlain by alternating clay-rich and sand-rich layers; see Figures 18, 19, and 20.

The water table beneath this area is normally situated within five feet or so of the land surface, but may rise to near-ground level during long, heavy storm events. Under relatively low water-level conditions, shallow groundwater flow is mainly to the east (see Figure 21). However, as the water table rises, the direction of flow also develops a north and south component toward drainage ditches (see Figure 22). Throughout the range of water levels that were observed, the garden-plot area was consistently found to lie hydraulically upgradient from the Fire Training Areas.

There aopears to be a limited degree of hydraulic separation between the water table and deeper water-bearing

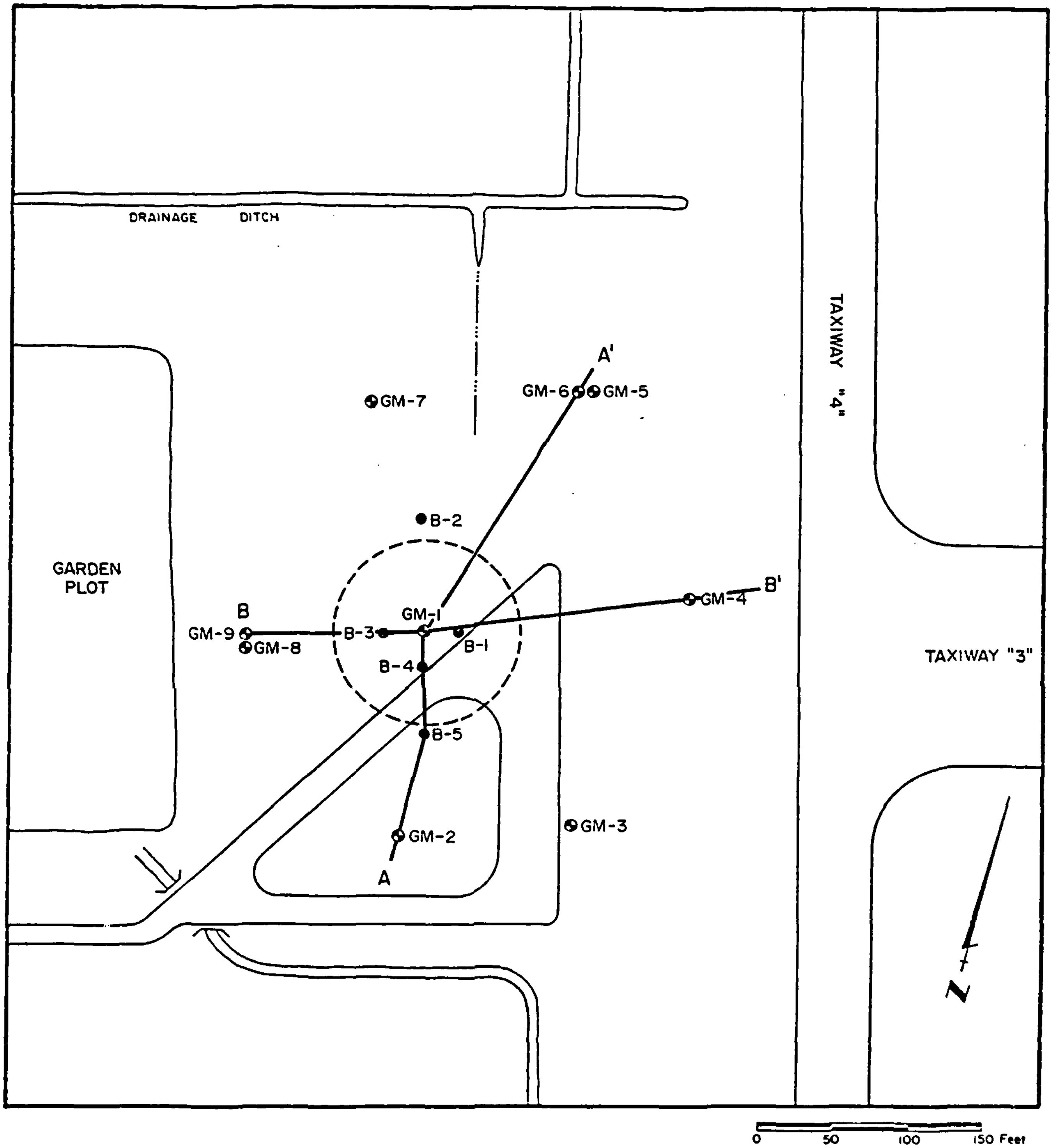


Figure 18. Locations of Inferred Geologic Cross-Sections A-A' and B-B', Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina

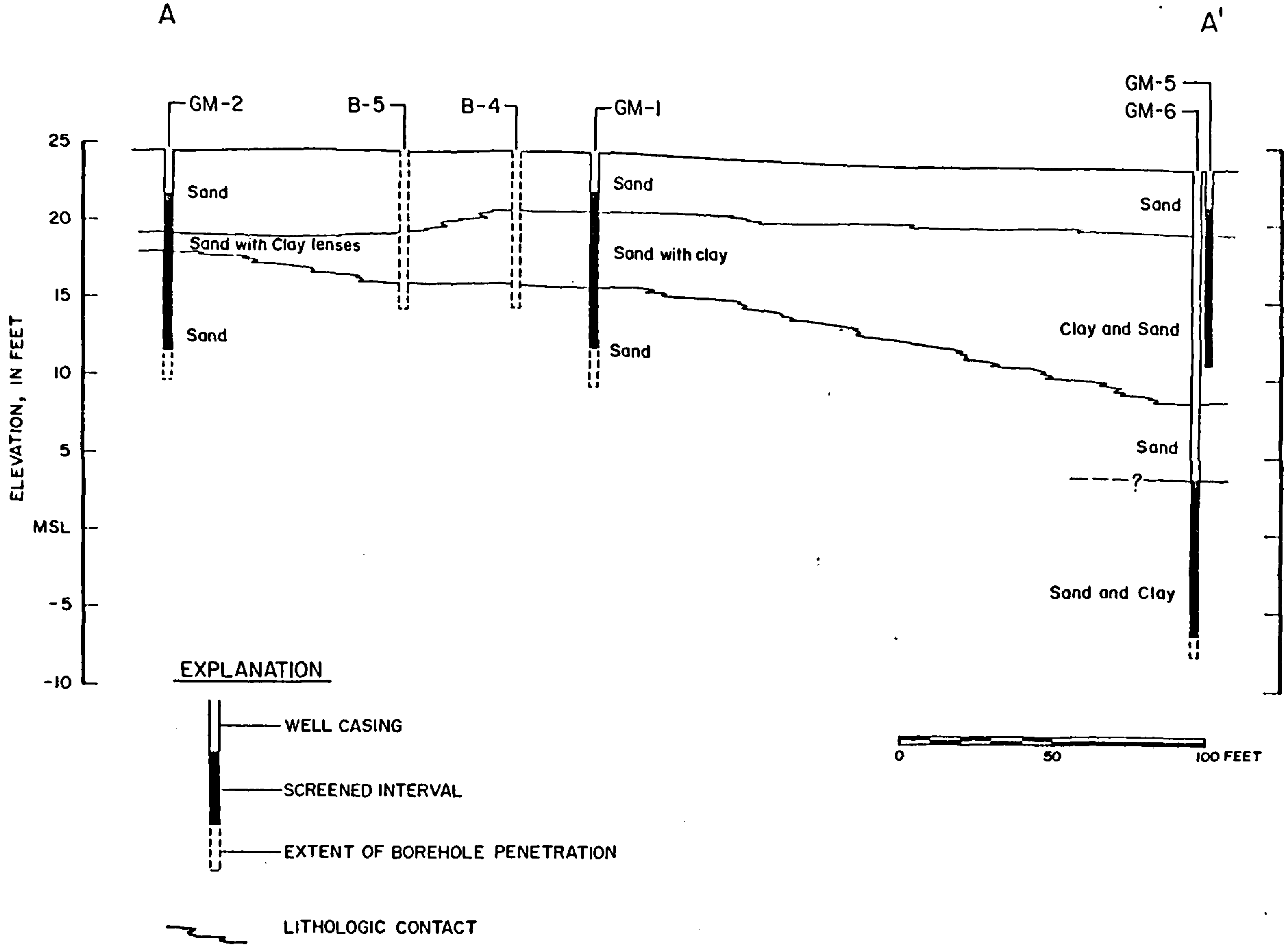


Figure 19. Inferred Geologic Cross-Sections A-A', Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina

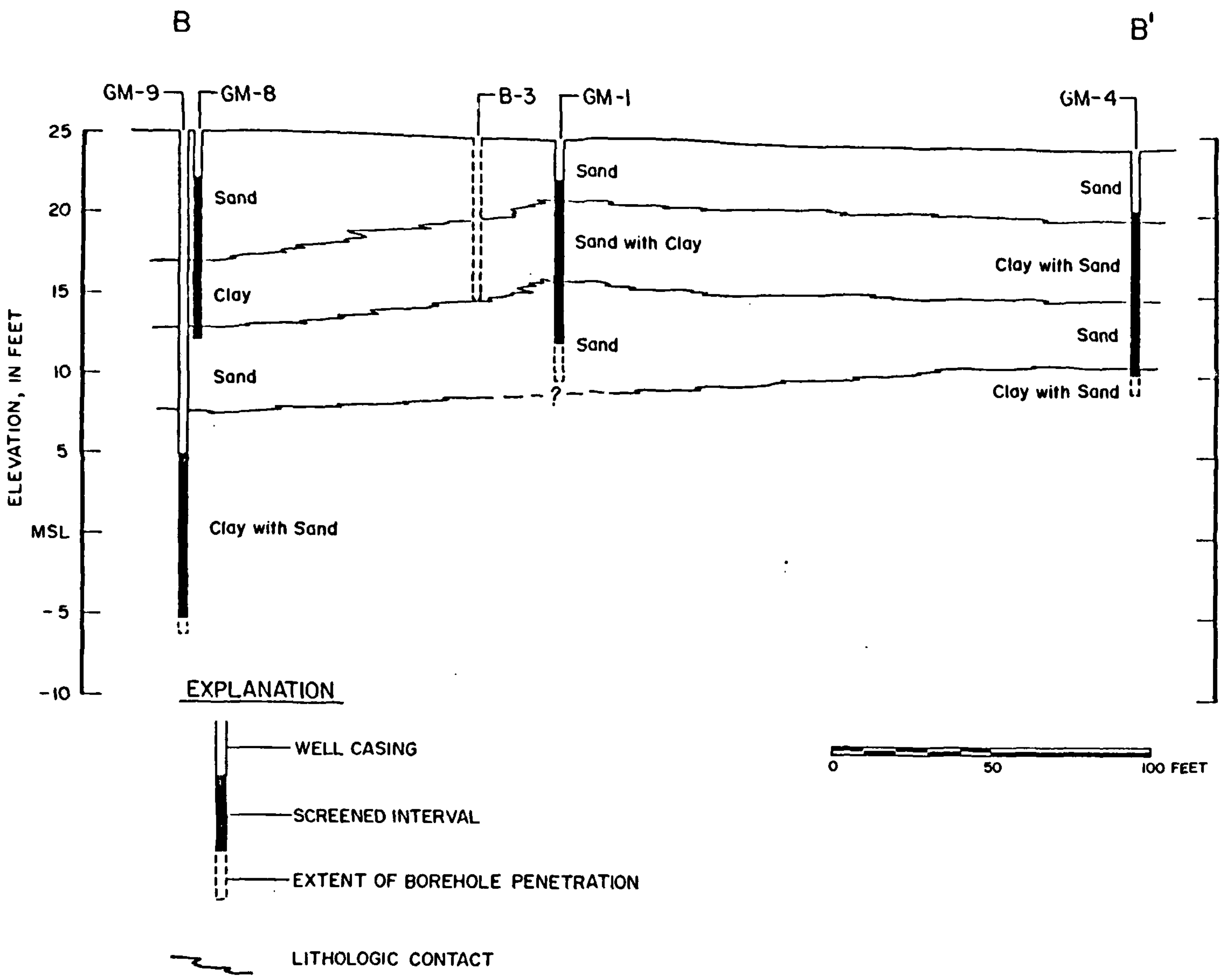


Figure 20. Inferred Geologic Cross-Sections B-B', Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina

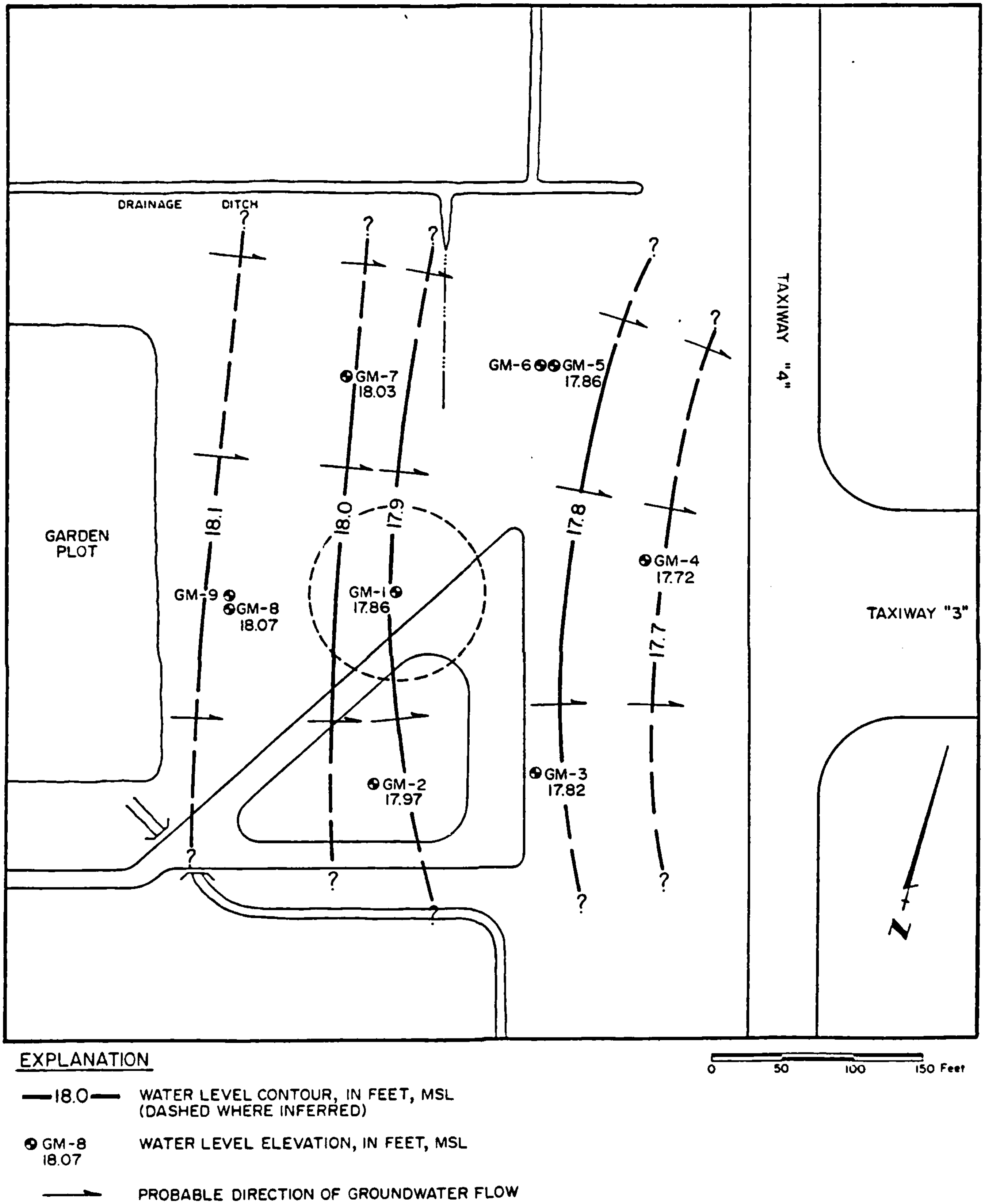


Figure 21. Inferred Shallow Groundwater Flow Patterns at Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina (based on 06/06/83 data)

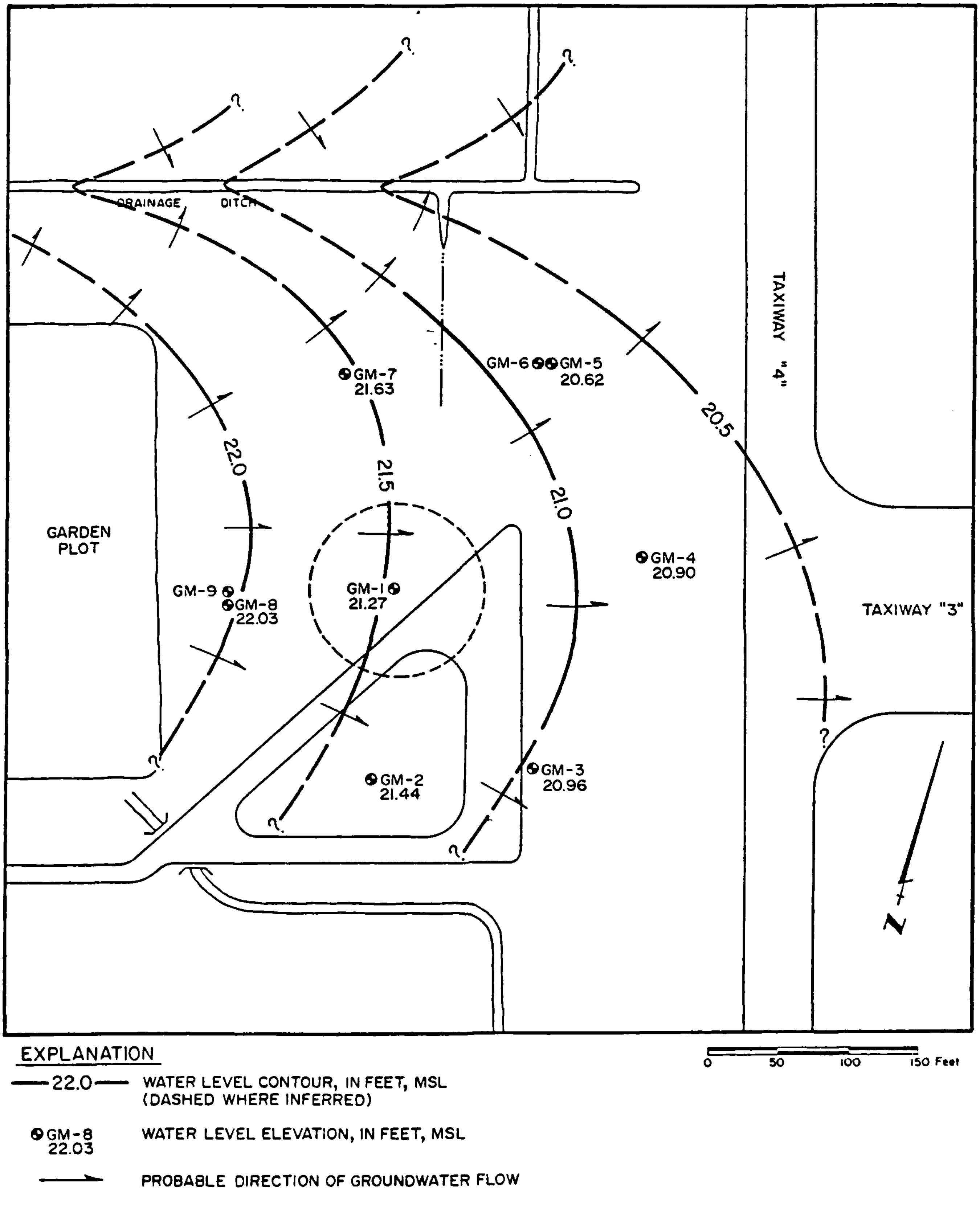


Figure 22. Inferred Shallow Groundwater Flow Patterns at Fire Training Areas #1 and #2, Myrtle Beach Air Force Base, South Carolina (based on 02/83 data)

unit (at depths of about 30 feet). Although a positive hydraulic head difference of 3 to 5 feet was measured between shallow and deep well pairs (Table 7), the degree of water-level fluctuation within the water-table and lower unit (over the same time period) was very similar, suggesting some hydraulic connection between these zones.

Groundwater Quality

The Fire Training Areas, as the name implies, were used for fire-control exercises (from 1955 to 1964), which basically consisted of pouring waste fuels, oils, and solvents onto the ground, igniting them, and extinguishing the fire with a protein foam. Although fluids may have undergone a considerable degree of incineration and volatilization, it is likely that appreciable quantities of organic compounds remained in the soil or infiltrated to the water table.

Organic vapor analyzer (OVA) inspections of shallow soils indicated organic vapor levels as high as 1000 parts per million (ppm) in some of the borings installed within, and downgradient from, the Fire Training Areas (see Appendix C). However, results of chemical analyses of groundwater samples from the area (Appendix G, Part G-1) indicate only low-level water quality degradation by organic compounds. Total organic carbon (TOC) concentrations were generally less than 10 milligrams per liter (mg/l) and were always less than 30 mg/l, and total organic halide (TOX) levels were usually below 0.05 mg/l and always below 0.17 mg/l.

Available data are not sufficient to define the exact cause(s) for observed differences between OVA and laboratory values. It is possible, for example, that volatile organic compounds have remained relatively immobile within shallow, unsaturated soils; thus, being more concentrated in the borehole headspace than in shallow groundwater. Another possibility is that the high OVA readings reflect levels of volatile compounds (such as methane) resulting from natural soil processes, that is, possibly the biodegradation of both natural and extraneous organic substances within the shallow system. One only can speculate, in fact, about the observed differences since the OVA was used only as a qualitative tool, principally for indicating the presence/ absence of volatile hydrocarbons (see Page 61).

Based on the initial set of chemical analyses (12/1982), samples from GM-1 and GM-4, (which exhibited the highest concentrations of TOC and/or TOX) were analyzed to identify and quantify specific volatile organic compounds (see 02/83 analyses). The sample from GM-1, which is situated directly in the midst of the Fire Training Areas, contained low levels of benzene (0.035 mg/l), chloroform (0.002 mg/l), toluene (0.01 mg/l), and ethyl benzene (<0.002 mg/l). The sample from GM-4, which lies hydraulically downgradient from the area, contained detectable concentrations of chloroethane (0.016 mg/l) and chloroform (0.003 mg/l). Owing to the generally low concentrations of contaminants, and the tendency for shifts in groundwater flow patterns beneath this area, discrete contaminant plumes are not apparent.

Samples from the deeper (±30-foot) wells (i.e., GM-6 and GM-9) were not analyzed for specific organic compounds. However, these wells were characterized by relatively low TOX values (about 0.04 mg/l) and TOC values of less than 4.0 mg/l, suggesting little degradation by organic chemicals.

LANDFILL #3/WEATHERING PIT #2

Hydrogeology

The Landfill #3/Weathering Pit #2 Area is situated near the northern boundary of the base, being bordered by deeply incised drainage ditches to the south and west, and thick trees and underbrush to the north. Surface materials throughout the midst of this area are comprised mainly of sandy to clayey fill and rubble that extend to depths of 3 feet or more. Fill materials are underlain and bordered by surficial clay deposits, ranging from 3 to 8 feet in thickness, which are underlain (to a depth of at least 30 feet) by layers of sand, clay, and sand (see Figures 23, 24, and 25).

The water table generally lies within 5 to 10 feet of the land surface, with groundwater flowing toward and discharging into the two deep drainage ditches (see Figures 26 and 27). Except for changes in hydraulic gradients, these flow patterns remained essentially the same during high and low water-level periods; gradients are steeper and groundwater flows more rapidly under higher water-level conditions. Water was observed in the deep drainage ditches, even during relatively dry periods (i.e., the 06/83

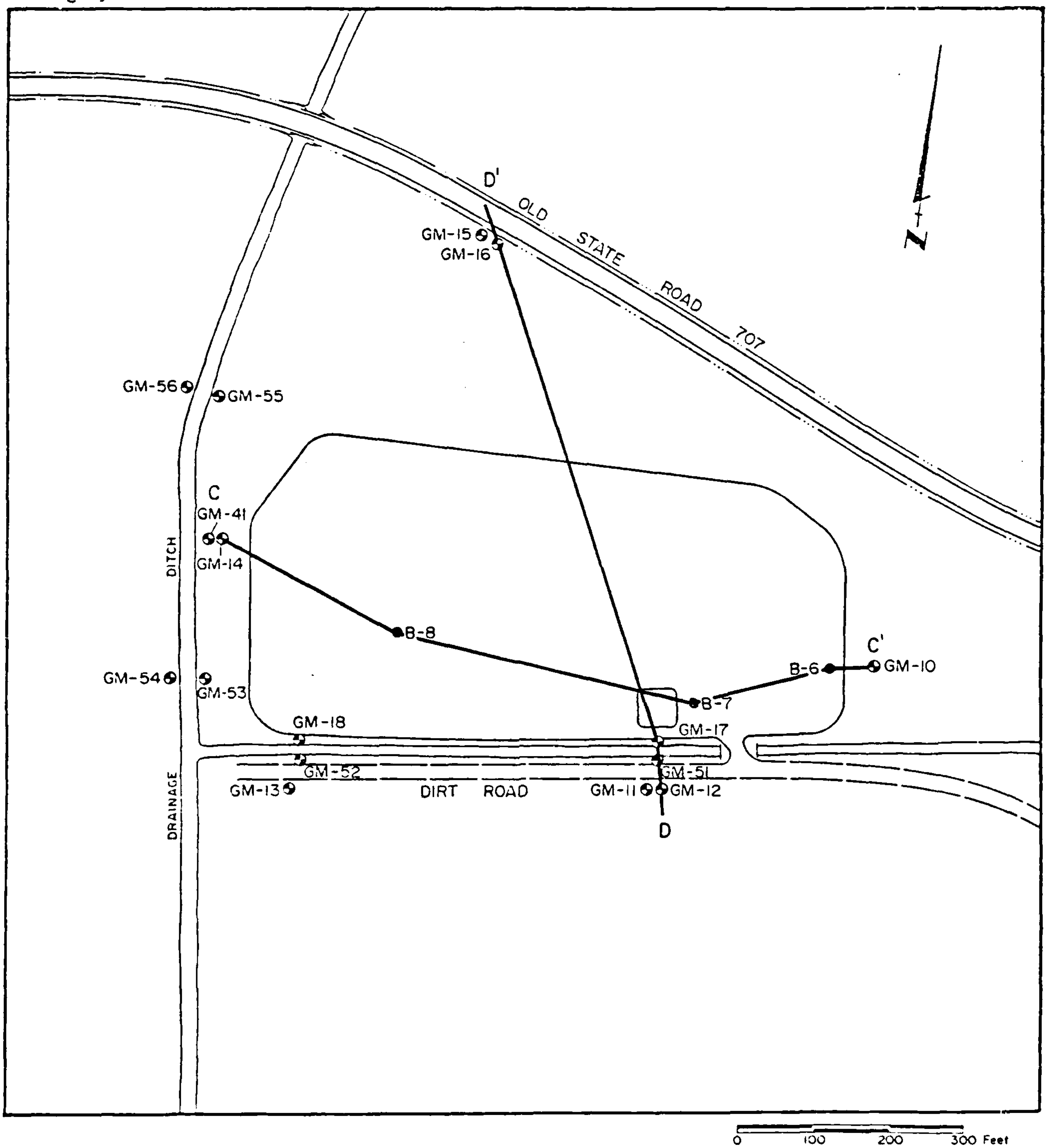


Figure 23. Locations of Inferred Geologic Cross-Sections C-C' and D-D', Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina

A shallow artesian unit is also present beneath the site, within the lowermost sand unit. Hydraulic head relationships between the water table and this unit were usually positive (favoring downward flow), but reversed during the dry monitoring period (see Table 7). These conditions indicate a fair degree of hydraulic separation between the two water-bearing units. Laboratory soil tests support this hypothesis, in that, the vertical permeability (Kv) determined for the confining clay layer is low - on the order of 4.6×10^{-8} cm/sec (see Table 6, sample GM-42).

Groundwater Quality

Fire Training Area #3 was used from 1965 to 1969 for the same type of routine exercises described earlier. However, concentrations of volatile organic compounds were appreciably higher than were observed in Fire Training Areas #1 and #2.

Shallow monitor wells around Fire Training Area #3 contained some of the higher levels of TOX, phenol, and volatile organic compounds that were observed at any of the sites investigated (see Appendix G, Part G-3).

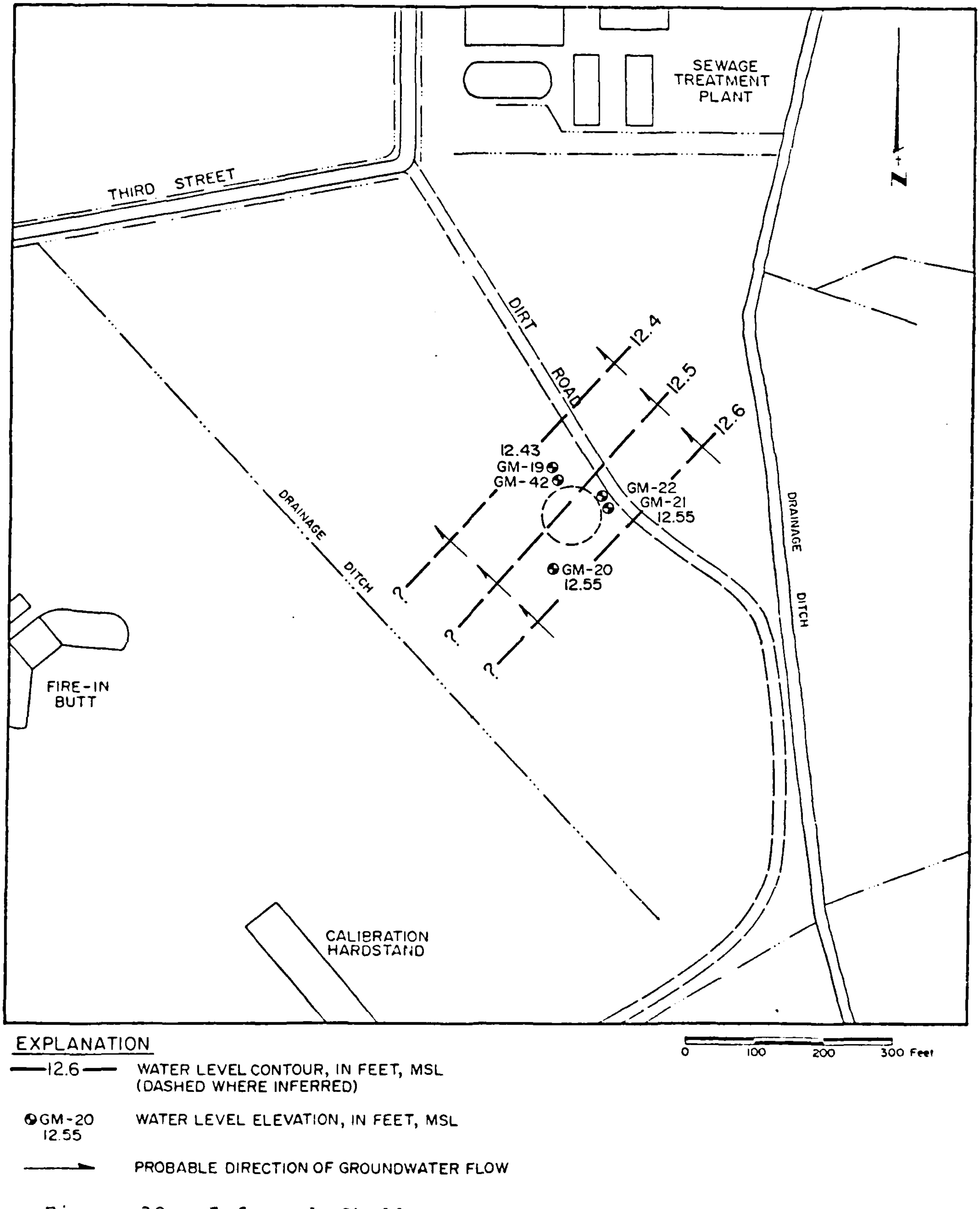


Figure 32. Inferred Shallow Groundwater Flow Patterns at Fire Training Area #3, Myrtle Beach Air Force Base, South Carolina (based on 06/83 data)

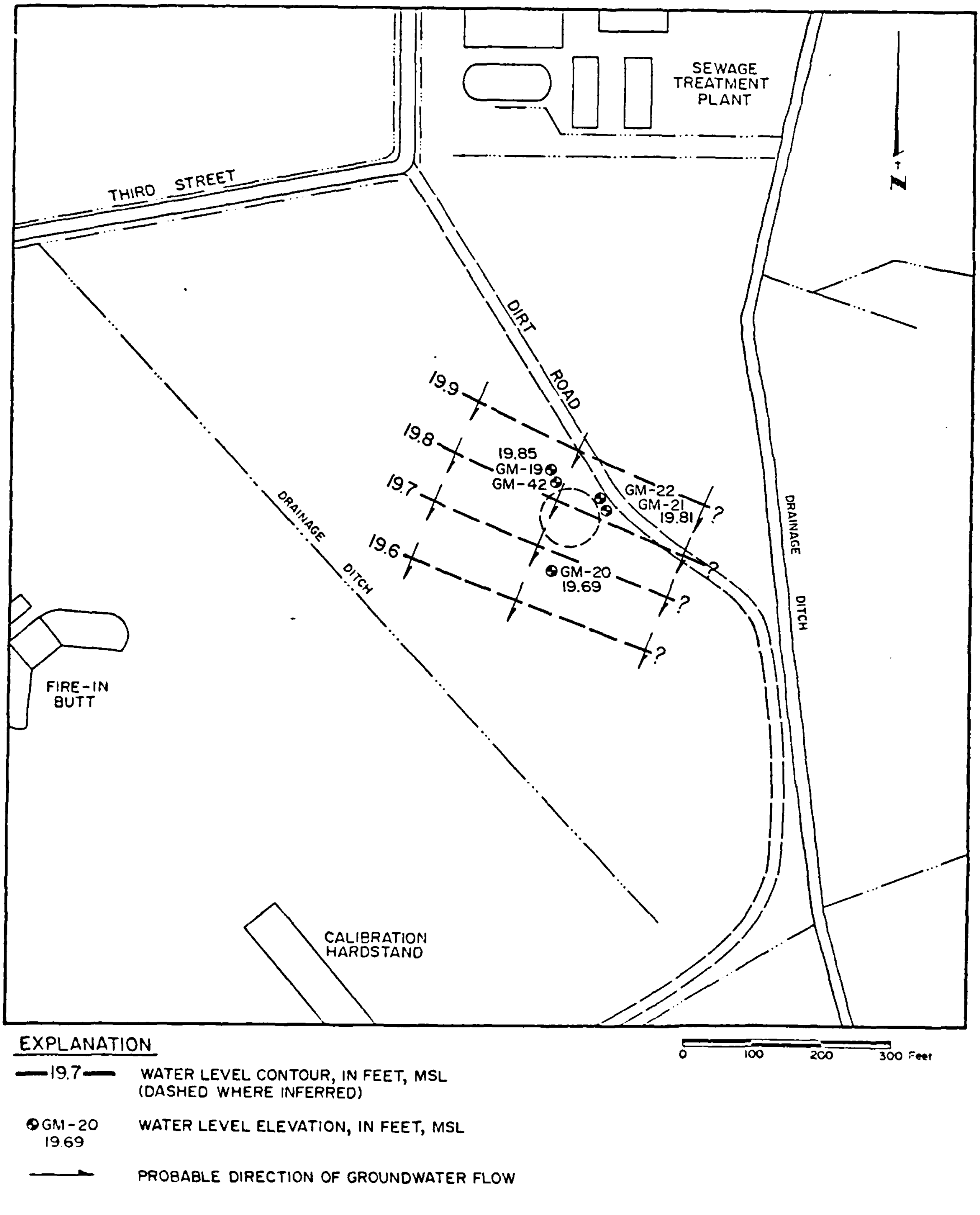


Figure 31. Inferred Shallow Groundwater Flow Patterns at Fire Training Area #3, Myrtle Beach Air Force Base, South Carolina (based on 02/83 data)

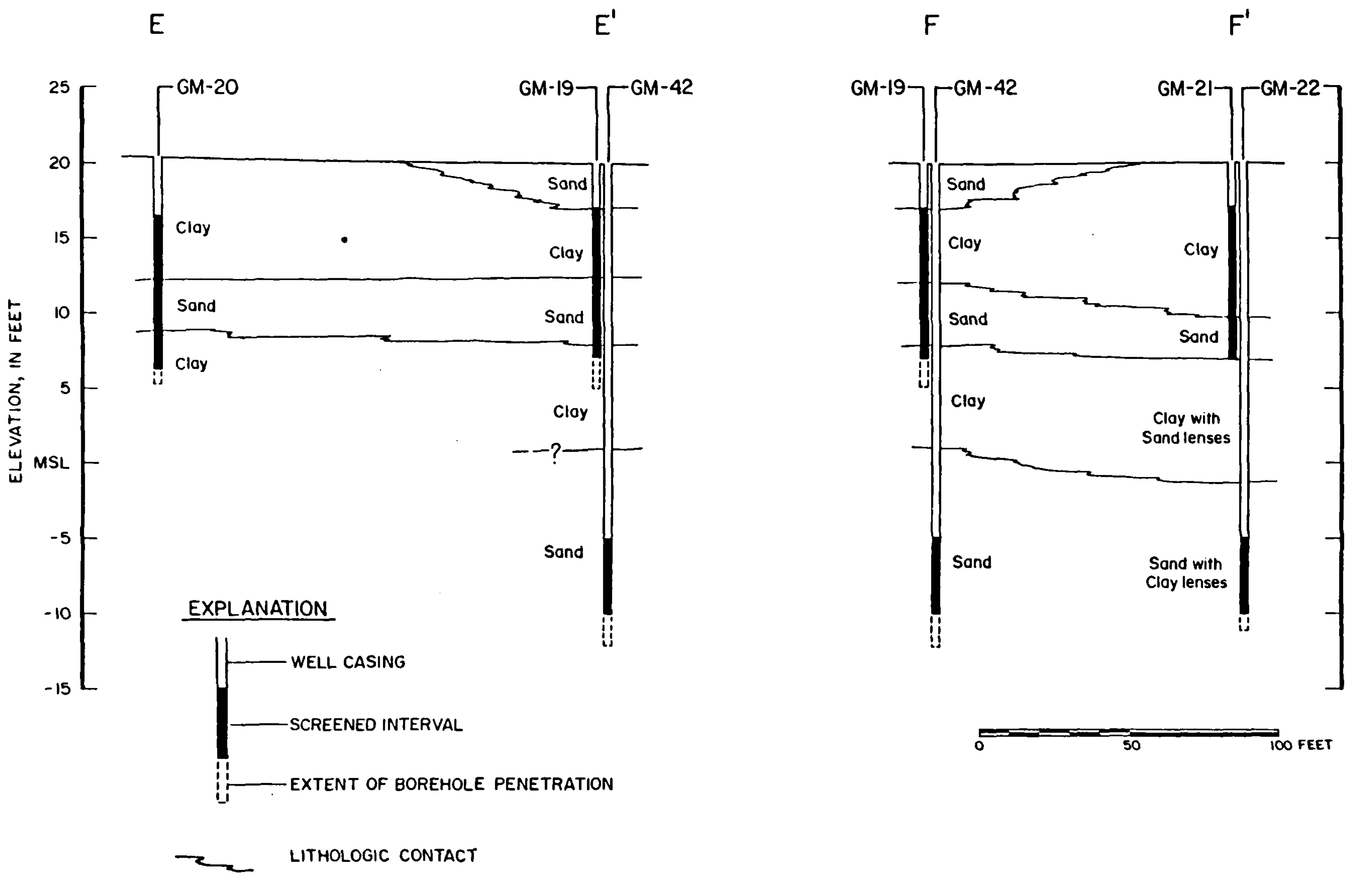


Figure 30. Inferred Geologic Cross-Sections E-E' and F-F', Fire Training Area #3, Myrtle Beach Air Force Base, South Carolina

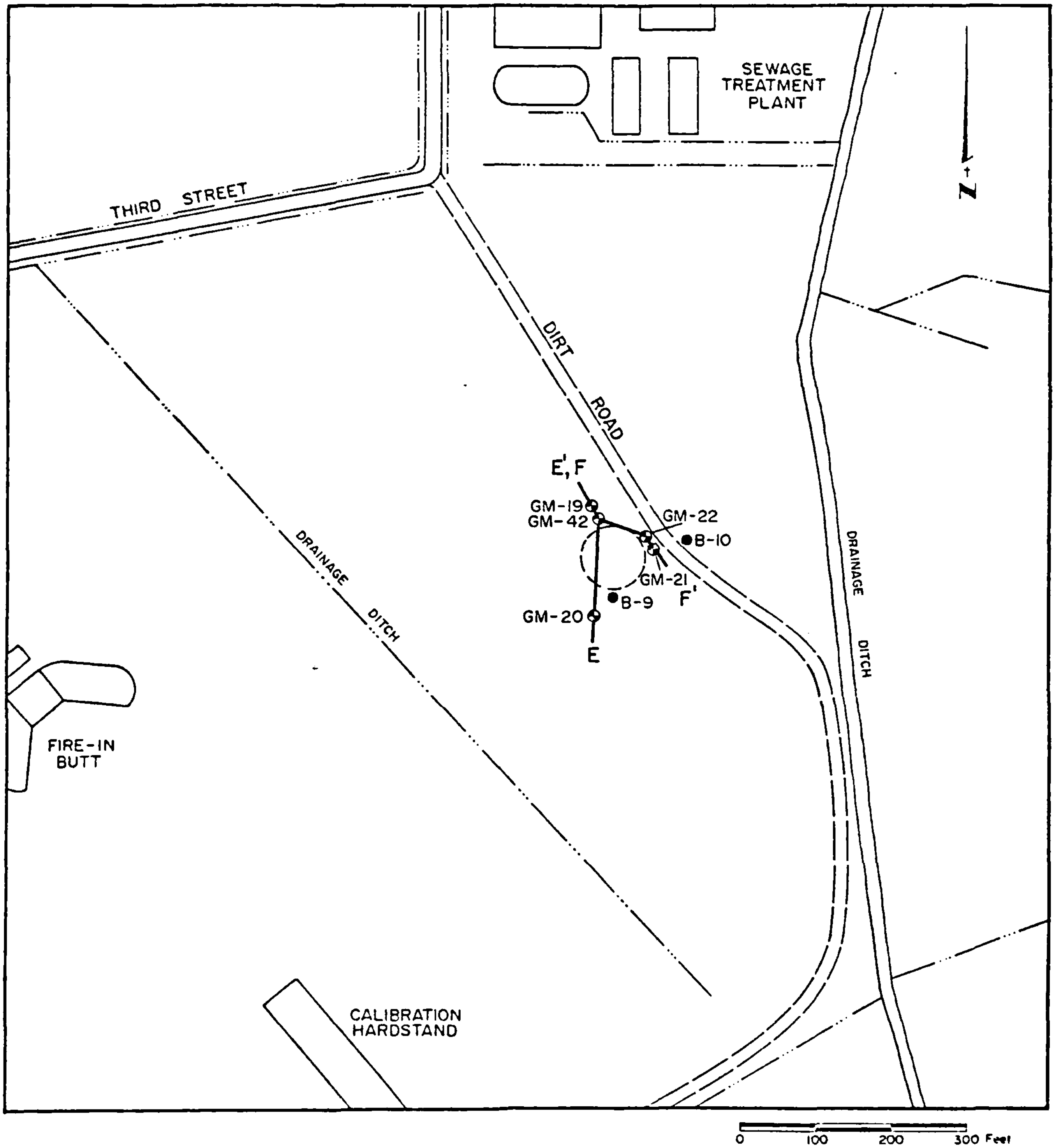


Figure 29. Locations of Inferred Geologic Cross-Sections E-E' and F-F', Fire Training Area #3, Myrtle Beach Air Force Base, South Carolina

FIRE TRAINING AREA #3

Hydrogeology

Fire Training Area #3 is located roughly midway along the northern boundary of the base, several hundred yards south of the sewage treatment plant. The area is flat-lying and is covered by medium-size pine trees and a thick layer of underbrush. Surficial sediments at this site consist mainly of clay and clay-rich materials, with a few shallow sand pockets. These deposits are underlain (to a depth of 30 feet or more) by layers of sand, clay, and sand (see Figures 29, and 30).

The water table beneath this site is essentially flat, with directions of groundwater flow changing by more than 90 degrees under varying weather conditions; during a wet time of the year (e.g., 02/83 monitoring period) the water table was at or near land surface and flow was toward a shallow drainage ditch to the southwest of the site (Figure 31); but, during a dryer period (6/83 monitoring event), flow shifted to the northwest (Figure 32). The overall water-table fluctuation between relatively wet and dry periods was more than 7 feet, representing the greatest change that was observed at any of the sites.

too, that these changes reflect changes in the source concentration. Withdrawing water from a well can result in influxes of water having different analyte concentrations. Also, variation in rainfall can affect the dilution factor and rate of water movement and thus concentration. The decrease in analytes in GM-17 probably reflects the cleanup of Weathering Pit #2 shortly before the start of the project. All of these wells are located between the Landfill/Weathering Pit facilities and the drainage ditches. The contaminant plumes in this area would likely be situated hydraulically downgradient from the facilities and would terminate at the drainage ditches.

Well points and shallow monitor wells located on the opposite side of the drainage ditches, and deep monitor wells installed into the artesian unit experienced very little water-quality degradation. This trend is a strong indication that: 1) drainage ditches in this area serve as hydraulic barriers to the lateral movement of groundwater (and contaminants) within the watertable system, and 2) the subsurface clay layer that confines the shallow artesian unit appears to have effectively blocked the vertical migration of contaminants into lower water-bearing zones (up to this point in time).

during and after 1976 for the disposal of grease and scum from anaerobic digesters. Weathering Pit #2, situated along the southeast border of Landfill #3, was used from 1979 to 1982 as a drying area for jet fuel filters and skimmer booms. In addition, this Weathering Pit also received unknown quantities of various liquid wastes such as oils, solvents, and paint strippers.

Water-quality analyses suggest that the shallow water table in areas hydraulically downgradient of these facilities has experienced varying degrees of groundwater degradation. In particular, monitor well GM-14 and well points GM-17, GM-18, GM-53, and to a lesser extent GM-55, all contain detectable concentrations of volatile organic compounds and generally exhibit elevated levels of TOX and specific conductivity (see Appendix G, Part G-2); higher conductivities probably result mainly from increased levels of bicarbonate, chloride, sodium, and possibly calcium. The volatile organic compounds detected included benzene, toluene, ethylbenzene, chloroform, chloroethylene, methylene chloride, 1,2-dichloroethane, 1,2-trans-dichloroethylene, chlorobenzene and 1,1-dichloroethane. As noted in Part G-2 of Appendix G, differences in such analytes as sulfate, TOC and TOX were measured at the different sample collection times. Such differences can be attributed to a number of factors including analyte loss or contamination after sample collection, repeatability of the measurement technique and simple analytical error. It is probable,

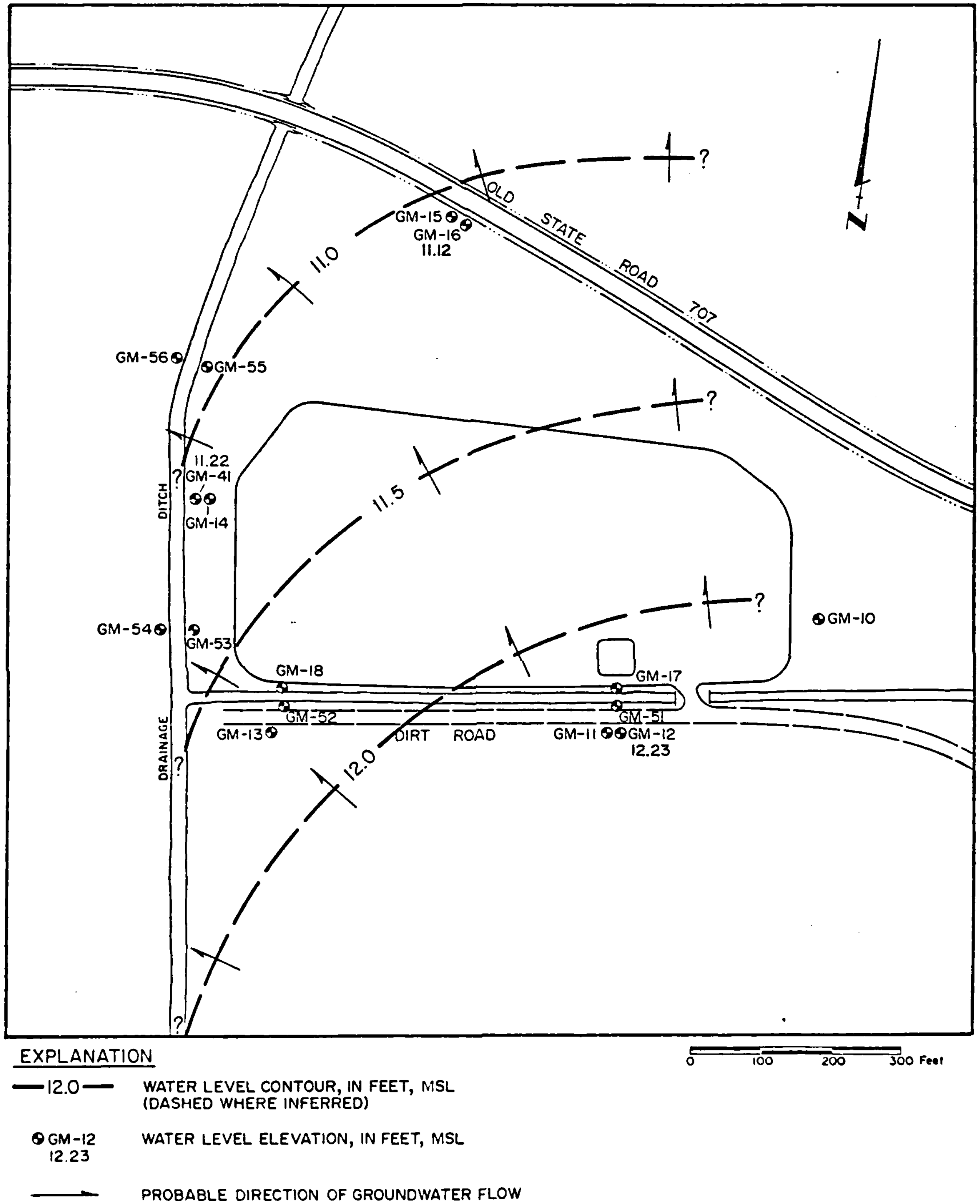


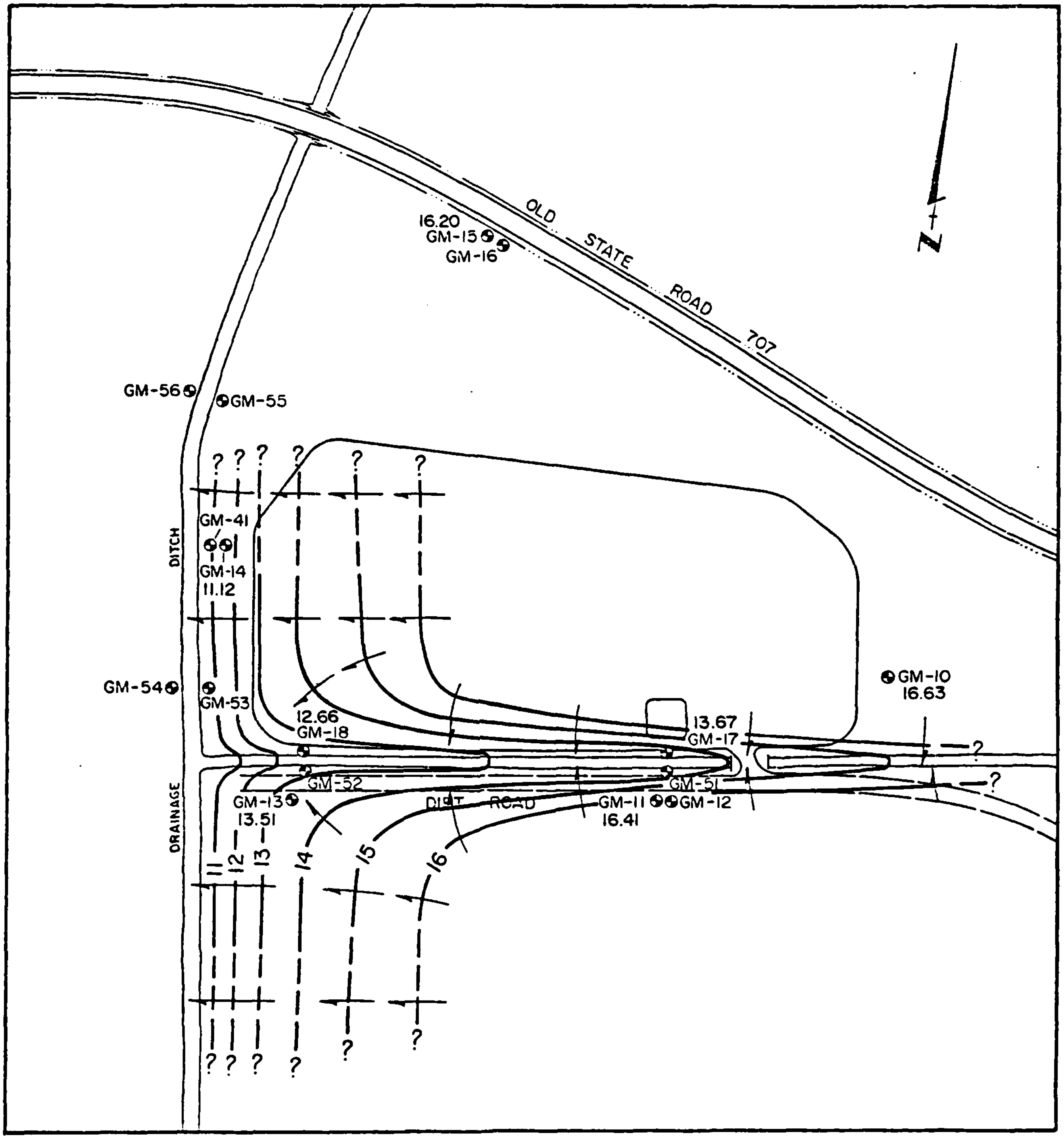
Figure 28. Inferred Groundwater Flow Patterns in the Shallow Artesian Unit at Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina (based on 06/83 data)

monitoring event), suggesting that the shallow water table has been sufficiently well intercepted to support base flow conditions.

A shallow artesian unit is also present beneath the site, within the lower sand body. Groundwater flow within this unit is generally to the north, toward the Intracoastal Waterway, but also appears to be locally influenced by the main drainage ditch located to the west of Landfill #3 (see Figure 28). Hydraulic head relationships between the water table and the artesian unit were generally positive (favoring downward flow), but became reversed during the relatively dry monitoring period (see Table 7). These observed conditions indicate that the two water-bearing units are fairly well separated by the confining clay layer. This idea is further supported by laboratory tests which indicate that the confining clay is characterized by a low vertical permeability (Kv) of roughly 1.0×10^{-7} cm/sec (see Table 6, sample GM-41).

Groundwater Quality

Landfill #3 (also the site of Weathering Pit #2) was used from 1964 to 1968 for the trench-and-cover disposal of general refuse; and was reopened for some period of time



EXPLANATION

—16— WATER LEVEL CONTOUR, IN FEET, MSL (DASHED WHERE INFERRED)

GM-11 16.41 WATER LEVEL ELEVATION, IN FEET, MSL

PROBABLE DIRECTION OF GROUNDWATER FLOW

Figure 27. Inferred Shallow Groundwater Flow Patterns at Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina (based on 02/83 data)

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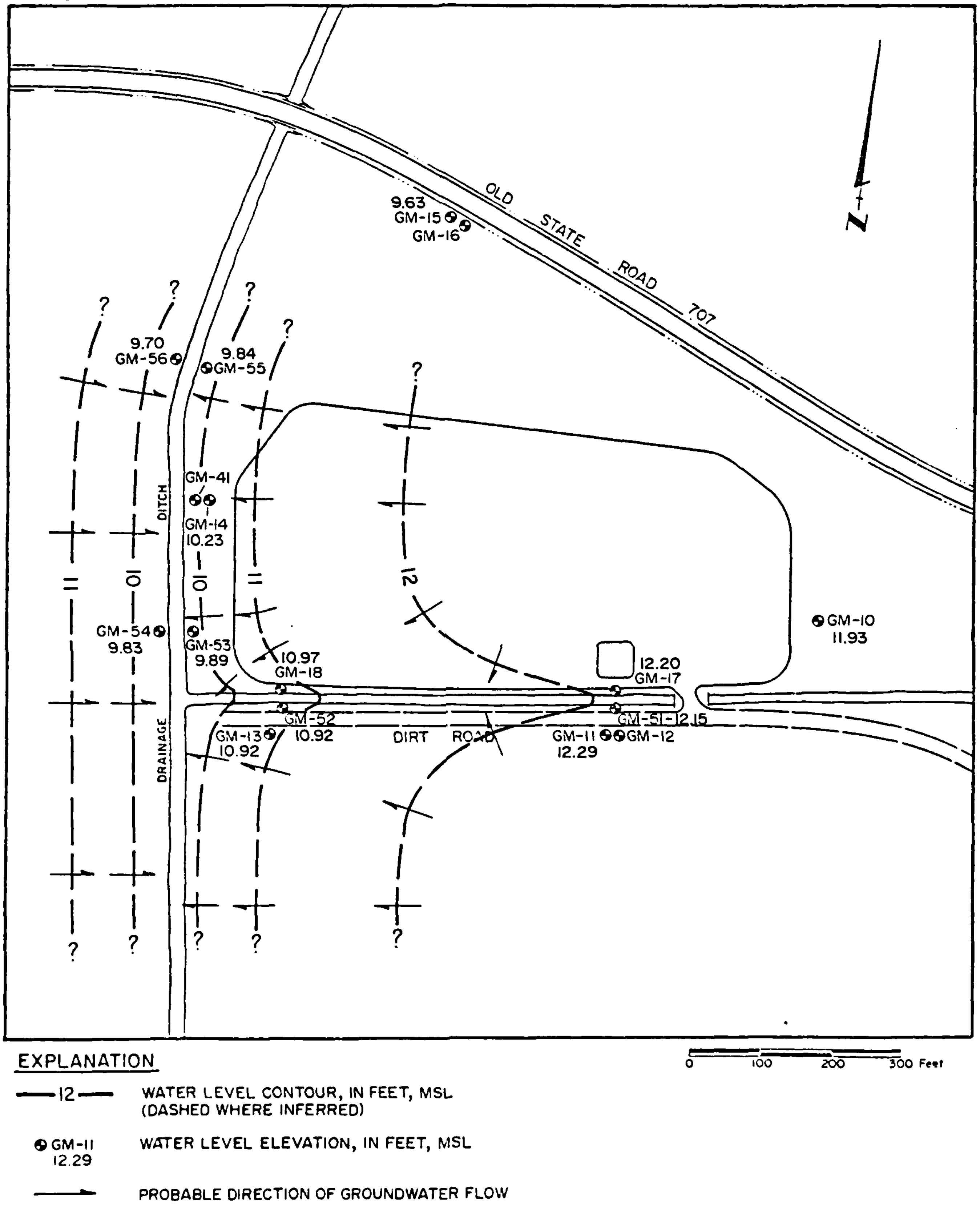


Figure 26. Inferred Shallow Groundwater Flow Patterns at Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina

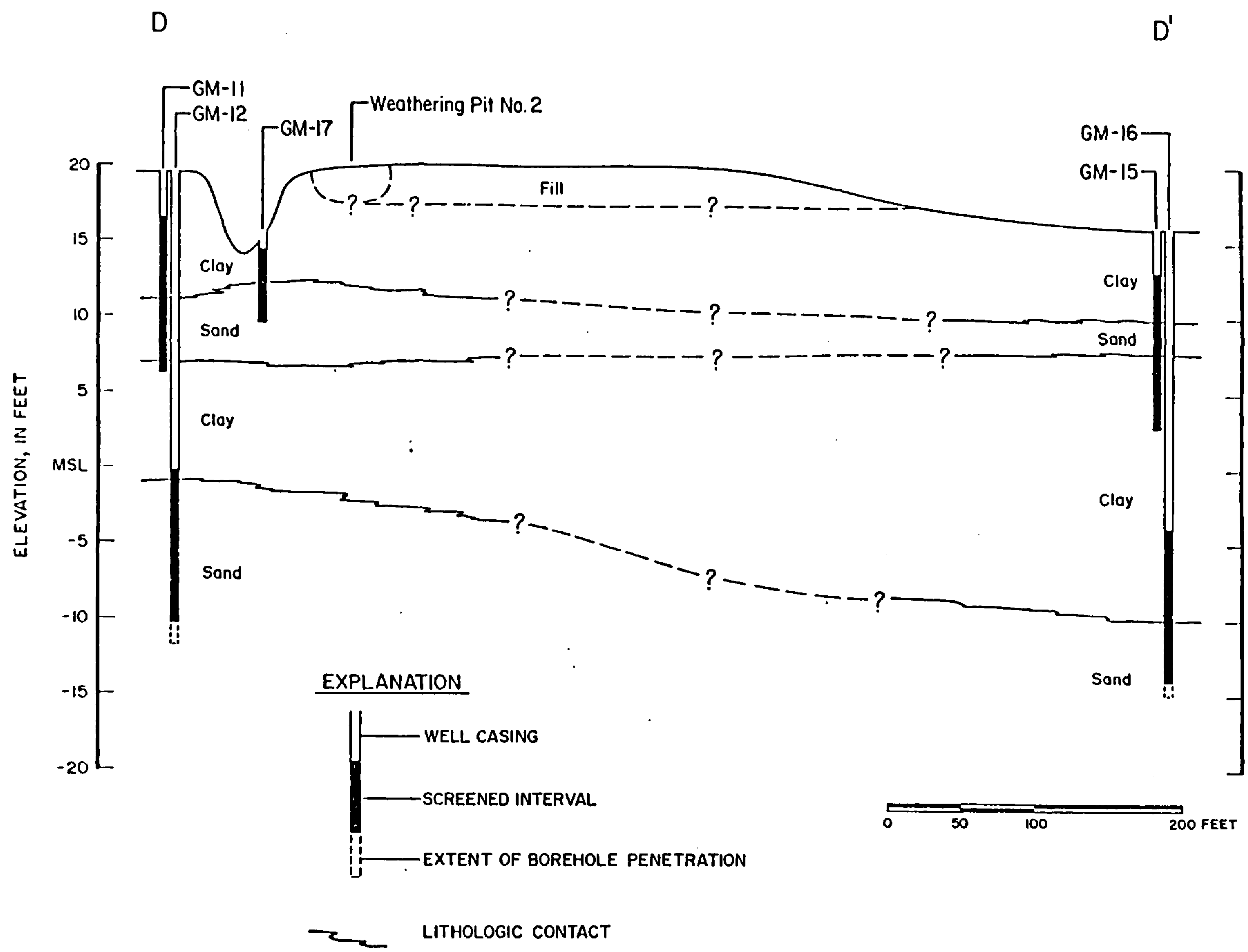


Figure 25. Inferred Geologic Cross-Section D-D', Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina.

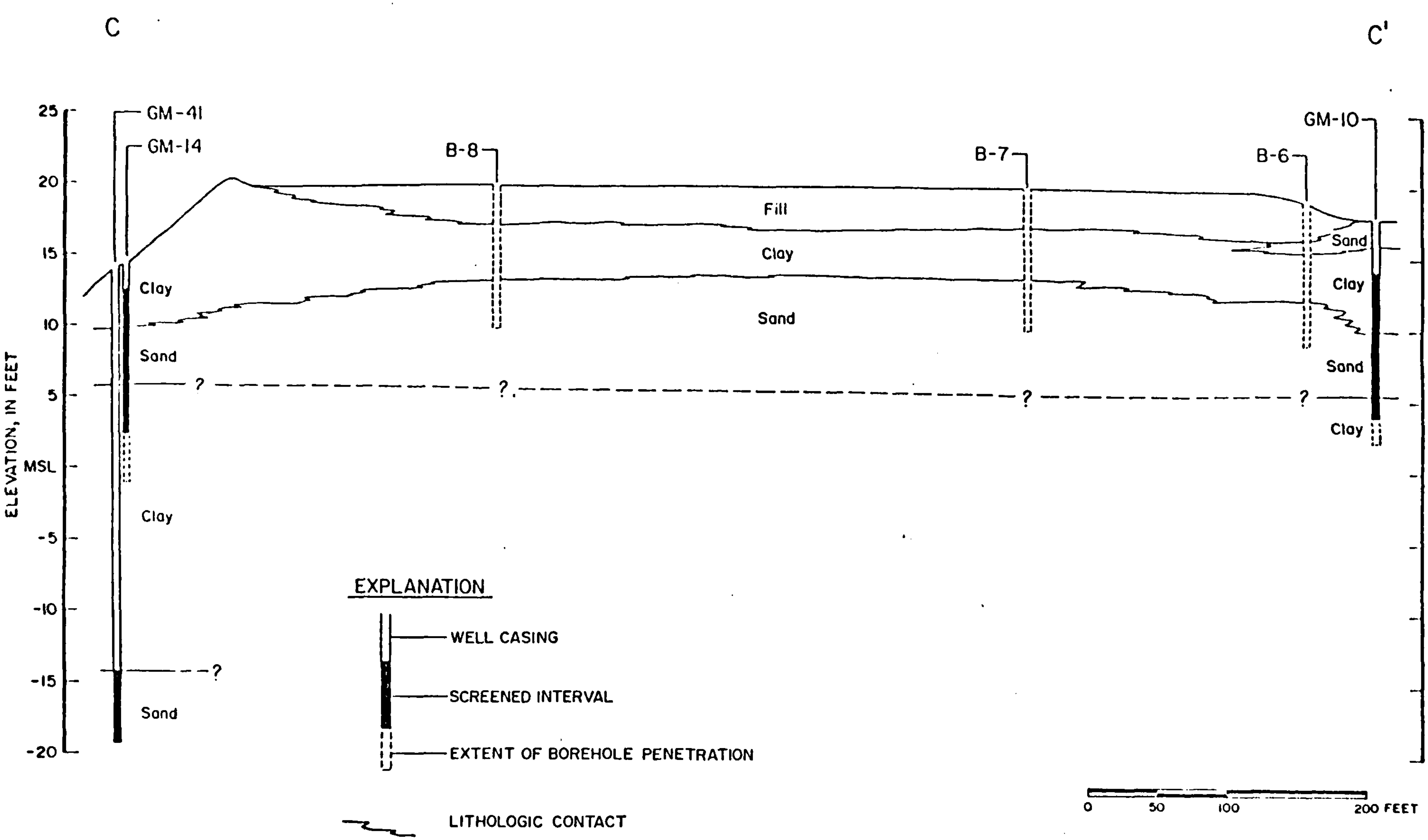


Figure 24. Inferred Geologic Cross-Section C-C', Landfill #3/Weathering Pit #2, Myrtle Beach Air Force Base, South Carolina.

In particular, monitor well GM-19 contained concentrations of chlorobenzene (3.1 mg/l), toluene (1.9 mg/l), ethylbenzene (0.96 mg/l), and benzene (0.71 mg/l) that are higher than most other wells (see 02/83 analyses). Owing to the slight hydraulic gradient, the clay-rich nature of surficial sediments, and the shifting groundwater flow patterns characterizing the shallow system, relatively high concentrations of various compounds in certain shallow monitor wells (e.g., GM-19) are thought to mainly reflect the proximity of these wells to localized point-source areas; i.e., contaminants are probably not extremely mobile and do not appear to form discrete plumes.

Degradation of groundwater quality within the shallow artesian unit (represented by wells GM-22 and GM-42) appears to be substantially reduced from that observed within the water table. Although TOX levels in GM-22 (12/82 analyses) are slightly elevated, specific analyses of samples from GM-42 found a TOX concentration of only 0.03 mg/l and non-detectable levels of all volatile organic compounds except 1,1-dichloroethane (0.0004 mg/l) and toluene (trace) (see 06/83 analyses). The better water quality within the artesian unit almost certainly reflects the low permeability of the confining clay layer, which appears to largely preclude the downward migration of contaminants.

WEATHERING PIT #1

Hydrogeology

Weathering Pit #1 is located in the mid-northwest portion of the base, being bordered by medium-depth drainage ditches to the south and west, and a fuel filter/boom evaporation area and a waste-fuel storage facility to the immediate east. This area is covered with short grass, and is underlain by surficial deposits consisting mostly of clay-rich sediments and some sandy fill material. These deposits are underlain (to depths of at least 35 feet) by distinguishable layers of sand, clay, and sand, respectively (see Figures 33 and 34). The lowermost clay unit is fairly extensive, ranging from 15 to 20 feet in thickness, and is characterized by a vertical permeability of about 1.3×10^{-7} cm/sec (see Table 6, sample GM-43).

The water table beneath this area is relatively flat and was encountered within 5 feet or less of the land surface; it fluctuated roughly 4.5 feet between the relatively wet (2/83) and dry (6/83) monitoring periods (see Appendix H for water-level data). Under both wet and dry conditions, groundwater flow is generally to the southwest, probably being largely influenced by a major drainage ditch system

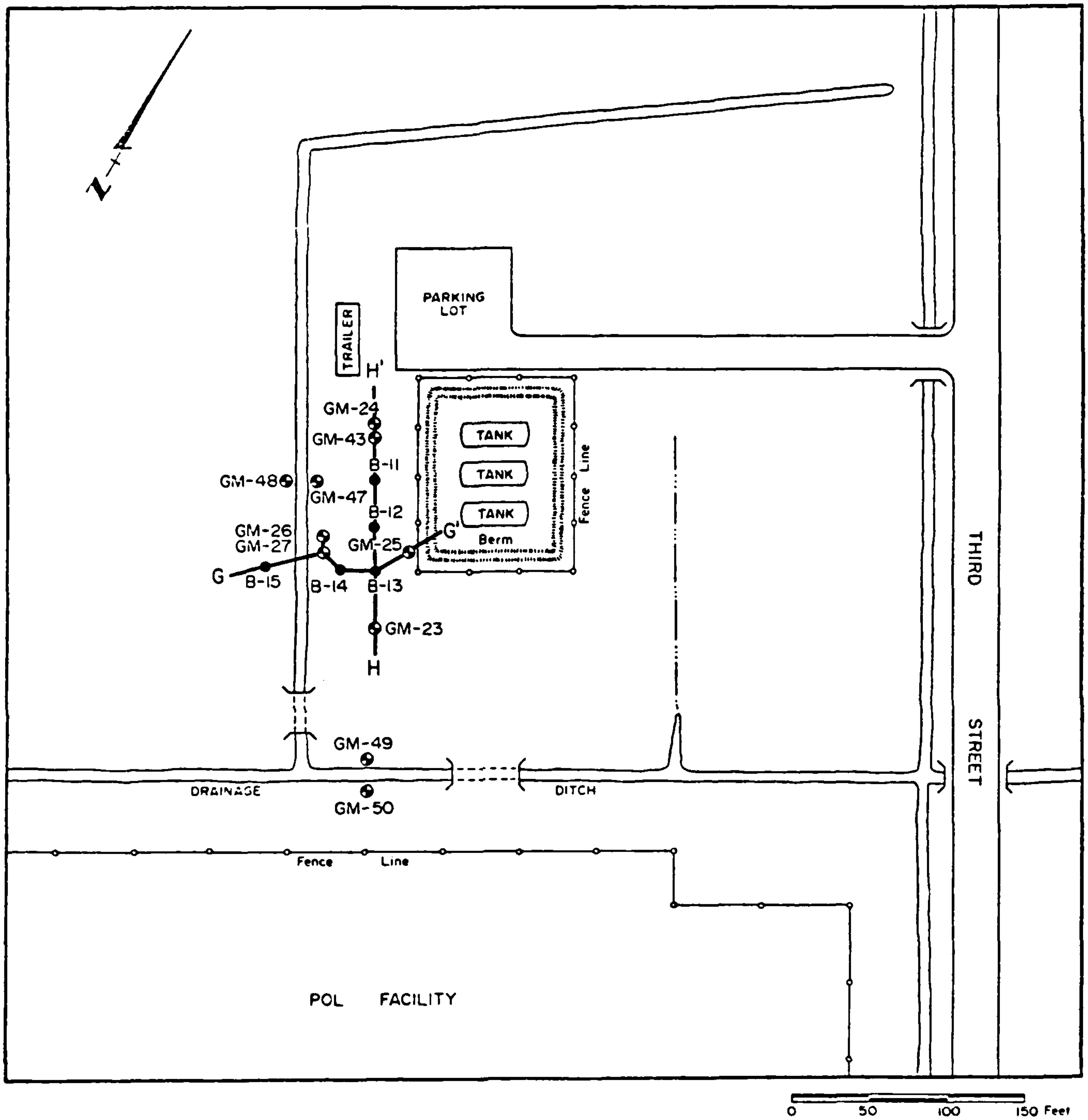


Figure 33. Locations of Inferred Geologic Cross-Sections G-G' and H-H', Weathering Pit #1, Myrtle Beach Air Force Base, South Carolina

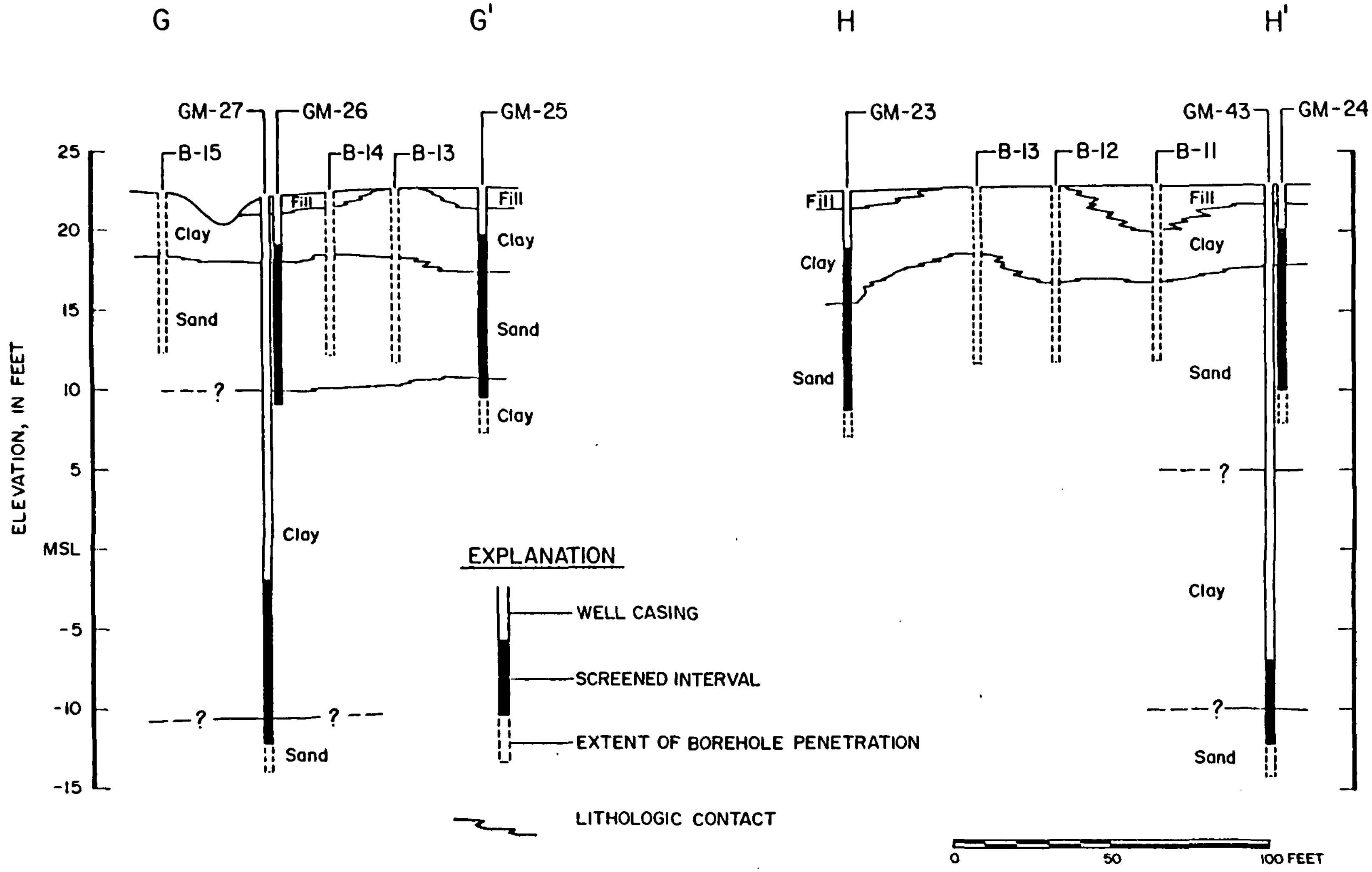


Figure 34. Inferred Geologic Cross-Sections G-G' and H-H', Weathering Pit #1, Myrtle Beach Air Force Base, South Carolina

("A") located about 800 feet west of this site. Medium-depth drainage ditches also appear to exert local influence on shallow flow patterns, under both wet and dry conditions (see Figures 35 and 36). Under wet, high waterlevel conditions, ditches probably intercept the top of the water table; under dry, lower water-level conditions, the water table may be preferentially drawn down within ditch areas because of evapotranspiration by trees and underbrush that cover portions of these alignments.

A shallow artesian unit (confined to semi-confined) is also present beneath this area, within the lowermost (30-foot-deep) sand body. Hydraulic head differences between the water table and this unit were always positive (favoring downward flow), but did become reduced during the relatively dry (6/83) monitoring period (see Table 7).

Groundwater Quality

Weathering Pit #1 was used from 1973 to 1978 as a drying/evaporation area for jet fuel filters and skimmer booms, and may have also received various sorts of liquid wastes such as oils, solvents, and paint strippers. Chemical analyses of groundwater samples from shallow monitor

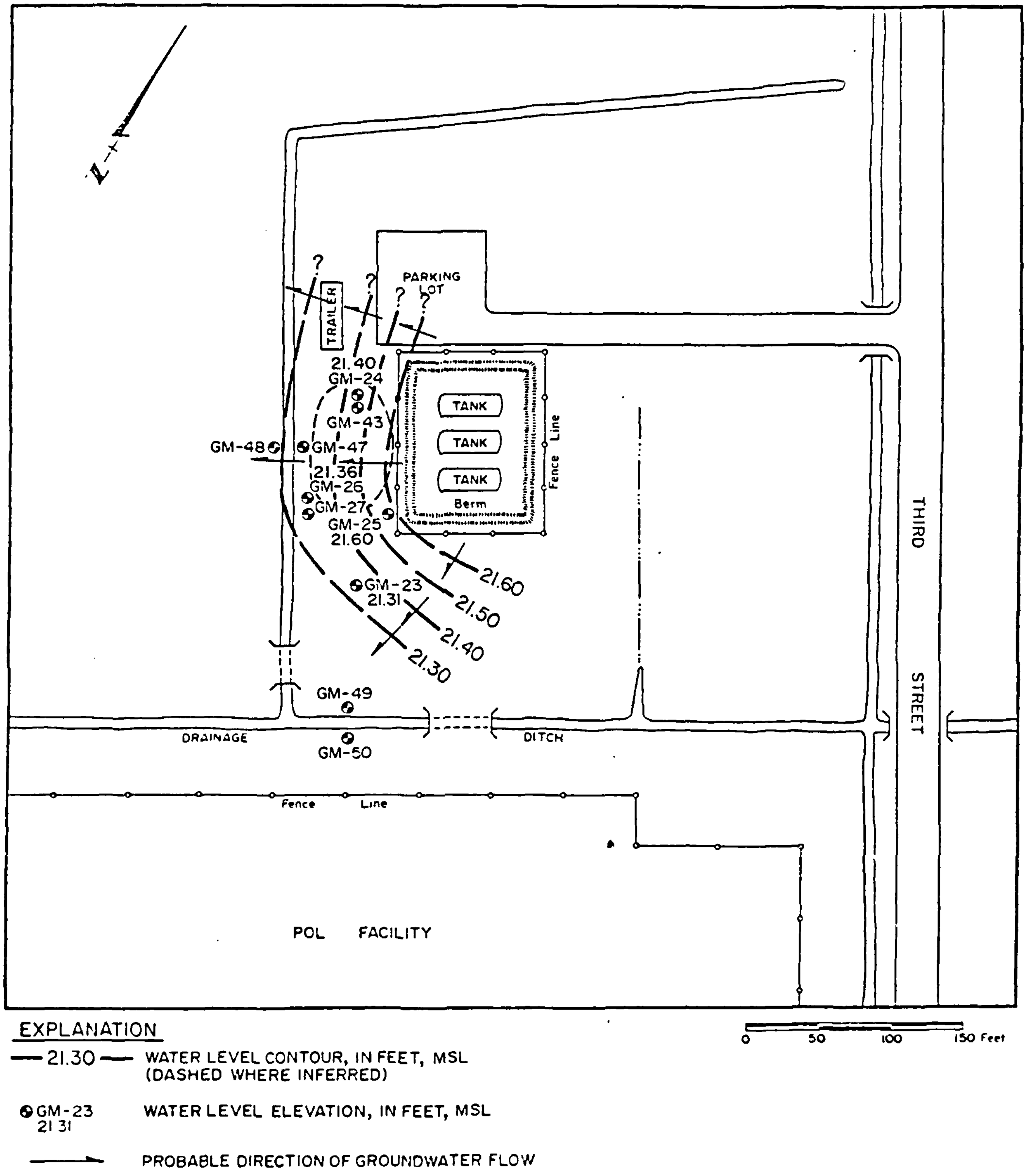


Figure 35. Inferred Shallow Groundwater Flow Patterns at Weathering Pit #1, Myrtle Beach Air Force Base, South Carolina (based on 02/83 data)

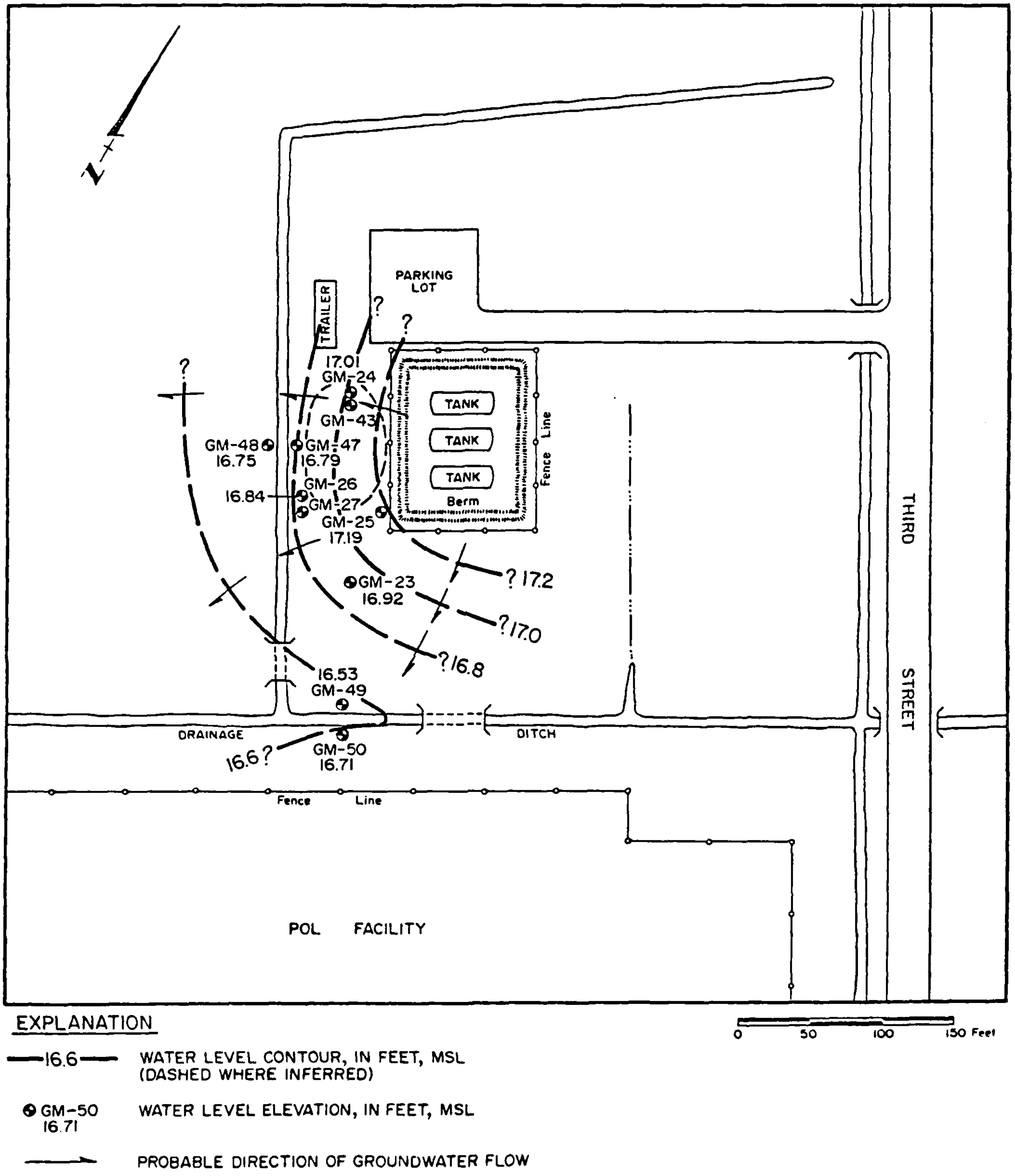


Figure 36. Inferred Shallow Groundwater Flow Patterns at Weathering Pit #1, Myrtle Beach Air Force Base, South Carolina (based on 06/83 data)

wells indicate that low to moderate levels of organic compounds are present in the water-table system beneath this site. Monitor well GM-24, however, contains some of the highest concentrations of volatile organics and TOX that were found at any of the sites during the 06/83 sampling and analysis effort (see Appendix G, Part G-4, Page G-16): benzene, ethylbenzene, toluene, and 1,2-trans-dichloroethylene are collectively present in the parts-per-million range. GM-24 is close to the fuel storage area and the active weathering site. The levels found in this well may represent a recent localized contamination event and not past usage of Weathering Pit No. 1. Continued monitoring of this and adjacent wells would further delineate the source of this contamination.

Data are not sufficient to accurately delineate a contaminant plume within the water-table system; however, it is apparent that contaminants become less concentrated with distance from the source area, and it is reasonable to assume that contaminants are moving in the direction of groundwater flow. Although drainage ditches in this area may, to some extent, influence local flow patterns, detectable concentrations of volatile organics in wells GM-48 and GM-50 (06/83 analyses) suggest that ditches do not totally block the lateral spread of contaminants; these wells are located along the sides of drainage ditches, opposite the facility.

Levels of volatile organic compounds within the shallow artesian unit wells GM-27 and GM-43 were substantially lower than in the water table, as indicated by relatively low TOX levels in GM-27 (12/82 analyses) and greatly reduced levels of benzene, toluene, ethylbenzene, and 1,2-trans-dichloroethylene in GM-43, relative to its shallow (GM-24) well pair (06/83 analyses). This trend suggests that the clay layer which confines the artesian unit also serves to reduce the downward migration of contaminants into this zone.

POL FUEL SPILL AREA

Hydrogeology

The POL area is located in the mid-northwestern portion of the base, being bordered by a medium-depth drainage ditch to the south, and a large fuel storage facility to the west. This area is fairly flat-lying, with surficial deposits consisting mainly of sand-rich sediments. These deposits are underlain by alternating clay and sand layers (four in all) to a depth of about 35 feet; see Figures 37 and 38.

During drilling, the water table was generally encountered within 5 feet of the land surface, and rose to near-ground level during the wet (2/83) monitoring period. Groundwater flow is basically to the south, apparently in the direction of the main drainage ditch; but, under relatively high water-level conditions, also tends to flow toward smaller, more shallow ditches that cut through the POL area (see Figures 39 and 40).

A shallow artesian unit was also encountered beneath the area at a depth of about 30 feet. Water-level data collected during the 6/83 monitoring period indicate a positive hydraulic head relationship between the water

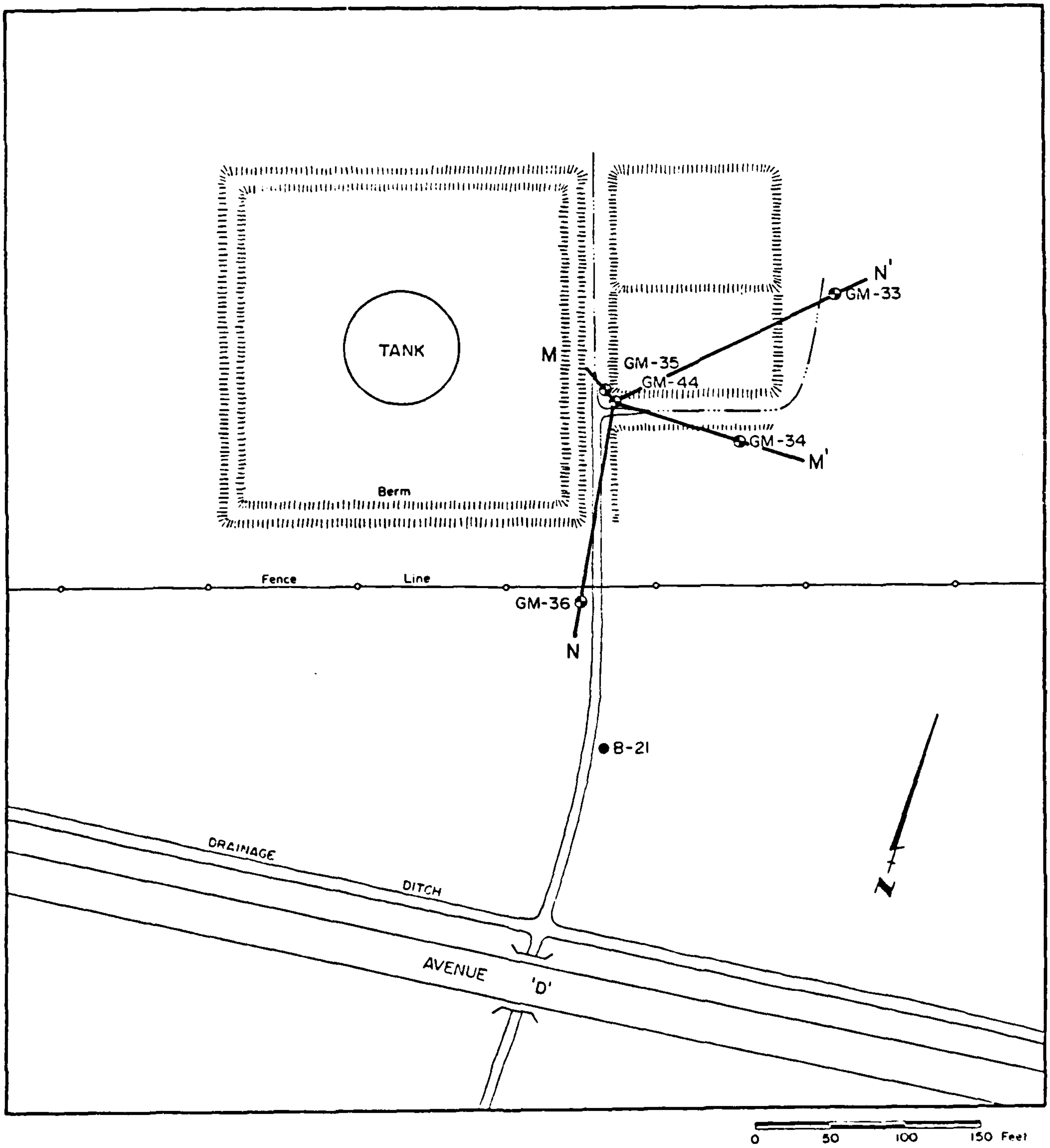


Figure 37. Locations of Inferred Geologic Cross-Sections M-M' and N-N', POL Area, Myrtle Beach Air Force Base, South Carolina

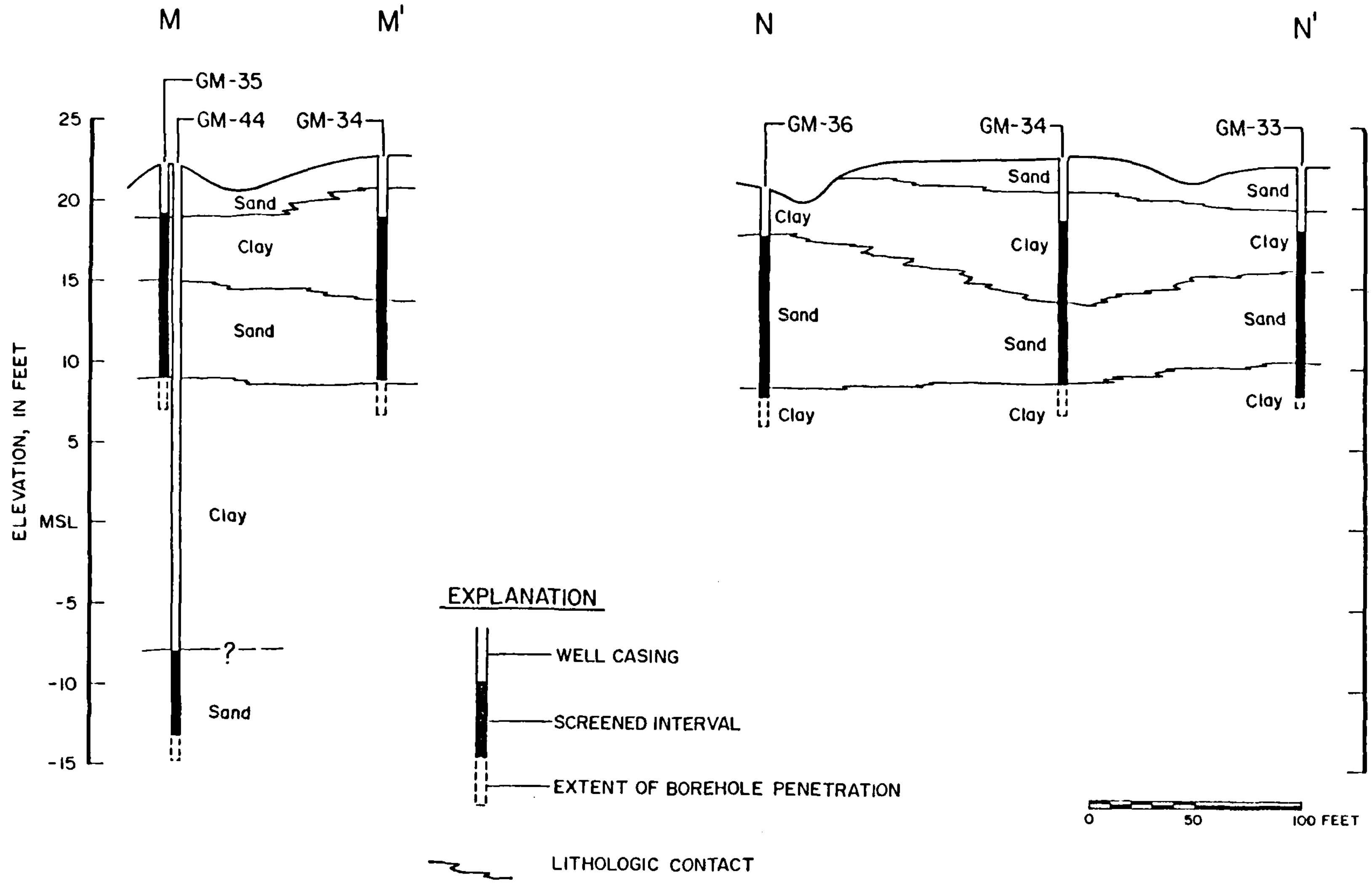


Figure 38. Inferred Geologic Cross-Sections M-M' and N-N', POL Area, Myrtle Beach Air Force Base, South Carolina

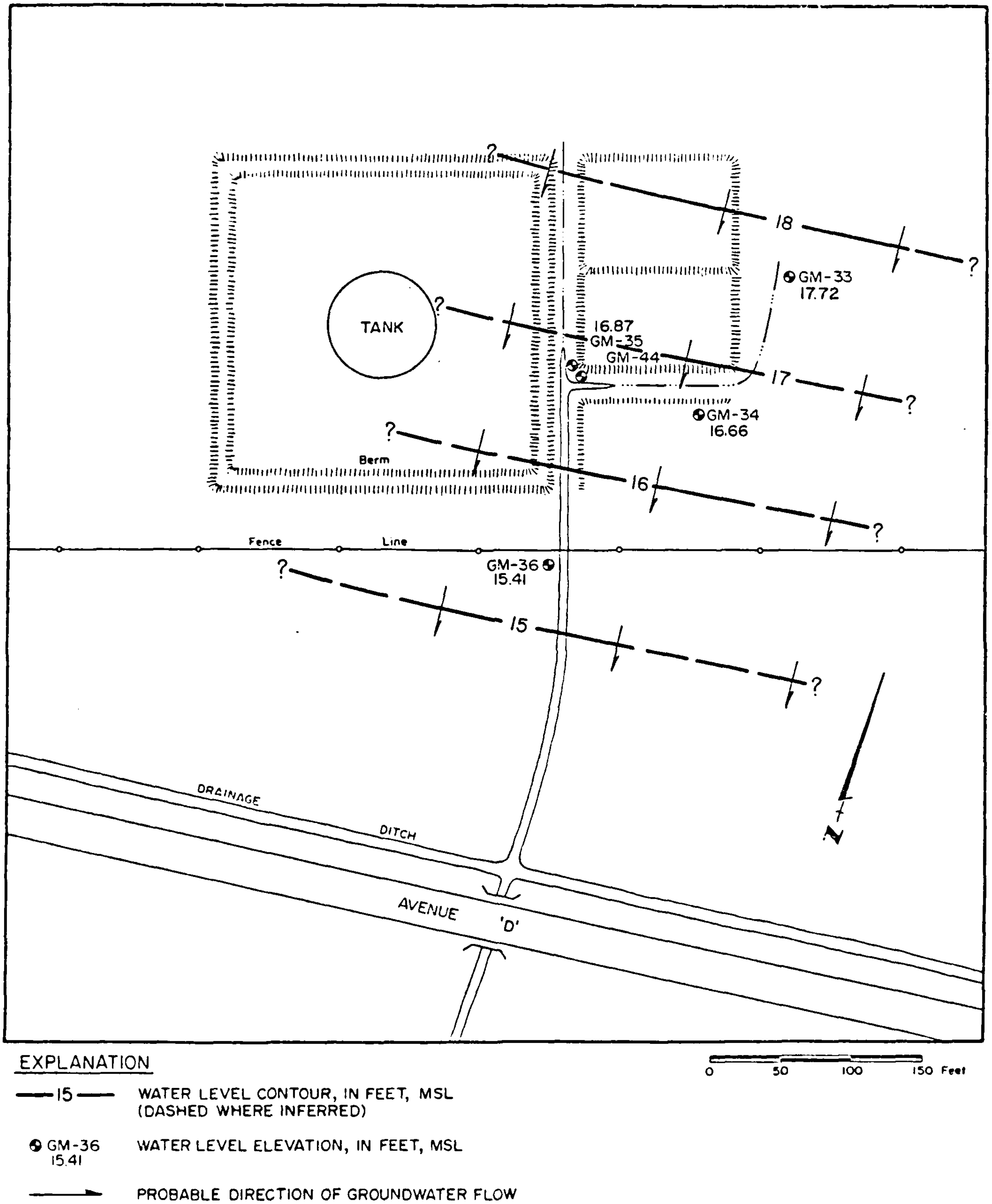
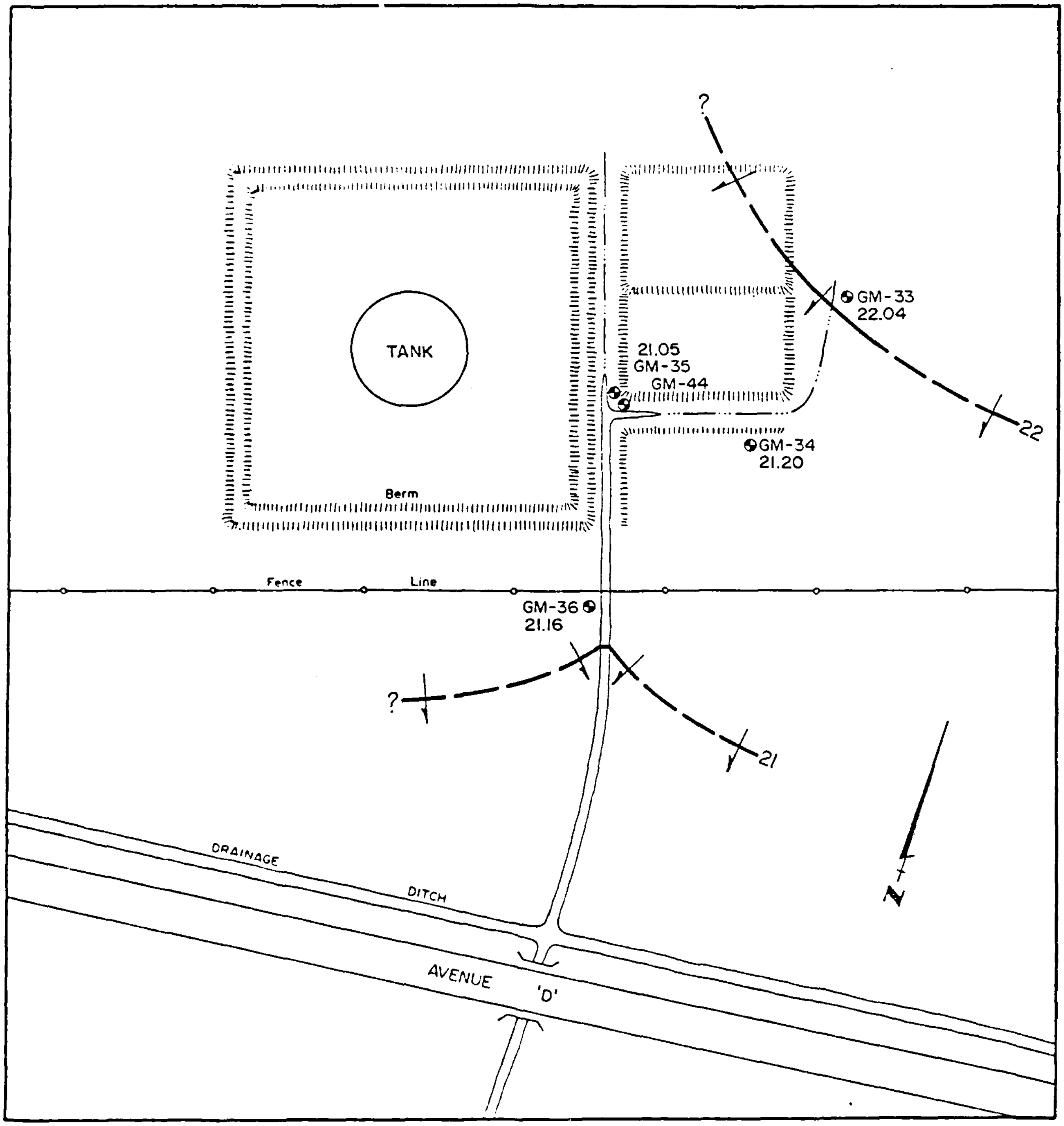


Figure 39. Inferred Shallow Groundwater Flow Patterns at the POL Area, Myrtle Beach Air Force Base, South Carolina (based on 06/83 data)



EXPLANATION

—22—	WATER LEVEL CONTOUR, IN FEET, MSL (DASHED WHERE INFERRED)
GM-33 22.04	WATER LEVEL ELEVATION, IN FEET, MSL
——→	PROBABLE DIRECTION OF GROUNDWATER FLOW

Figure 40. Inferred Shallow Groundwater Flow Patterns at the POL Area, Myrtle Beach Air Force Base, South Carolina (based on 02/83 data)

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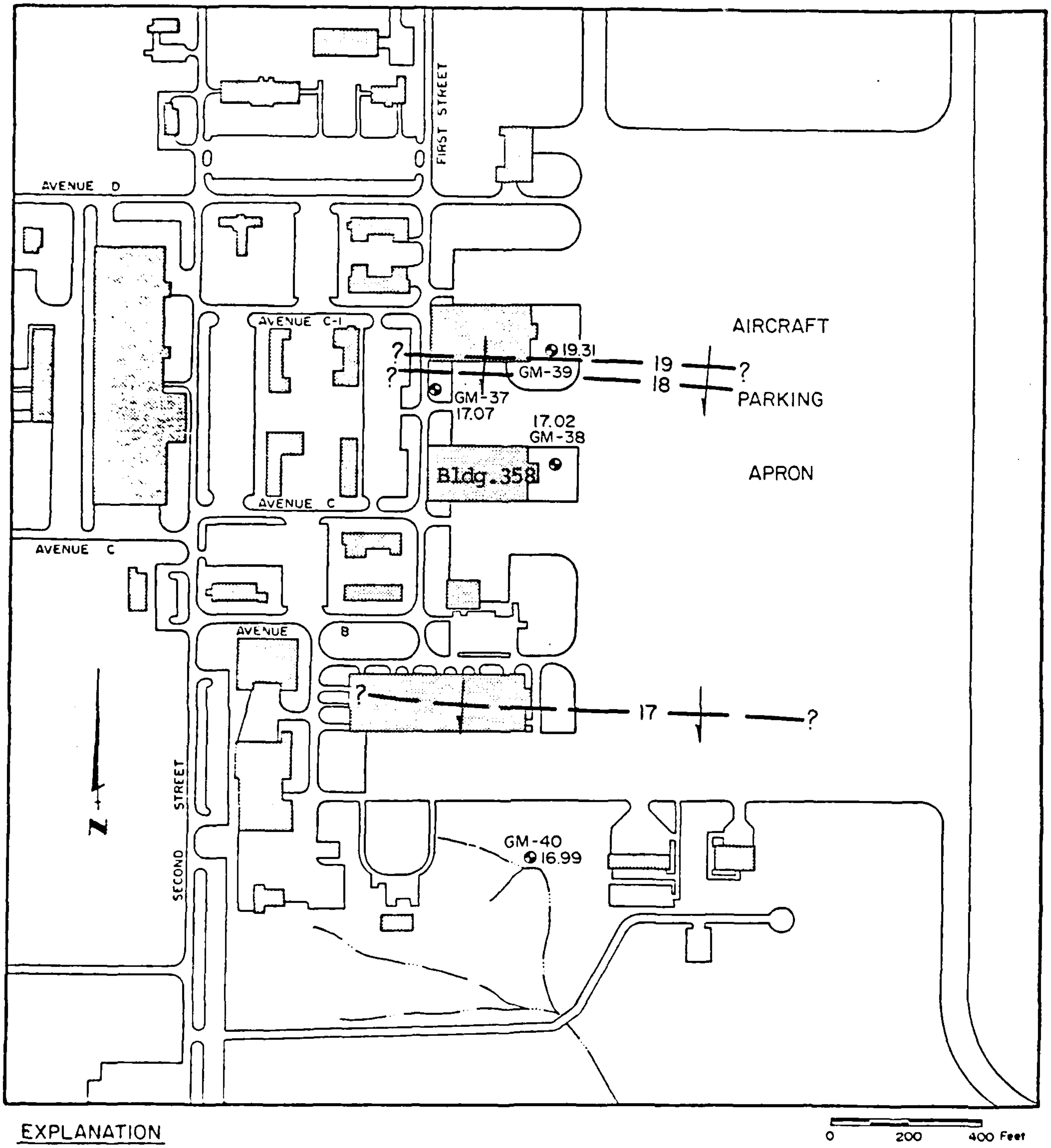


EXPLANATION

—19—	WATER LEVEL CONTOUR, IN FEET, MSL (DASHED WHERE INFERRED)
GM-39 19.31	WATER LEVEL ELEVATION, IN FEET, MSL
———	PROBABLE DIRECTION OF GROUNDWATER FLOW

Figure 48. Inferred Shallow Groundwater Flow Patterns at the Flight Line Area, Myrtle Beach Air Force Base, South Carolina (based on 12/82 data)

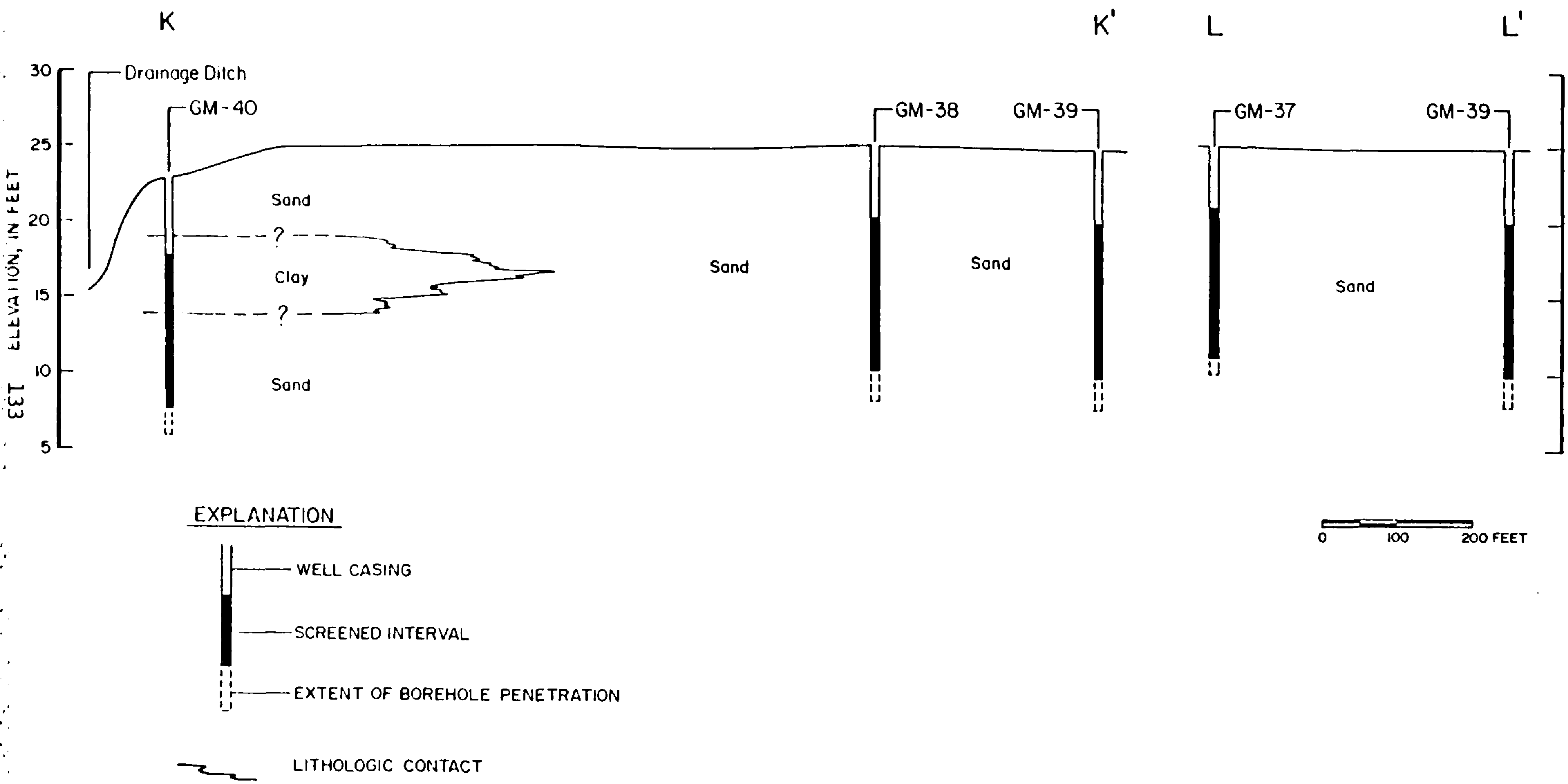


Figure 47. Inferred Geologic Cross-Sections K-K' and L-L', Flight Line Area, Myrtle Beach Air Force Base, South Carolina

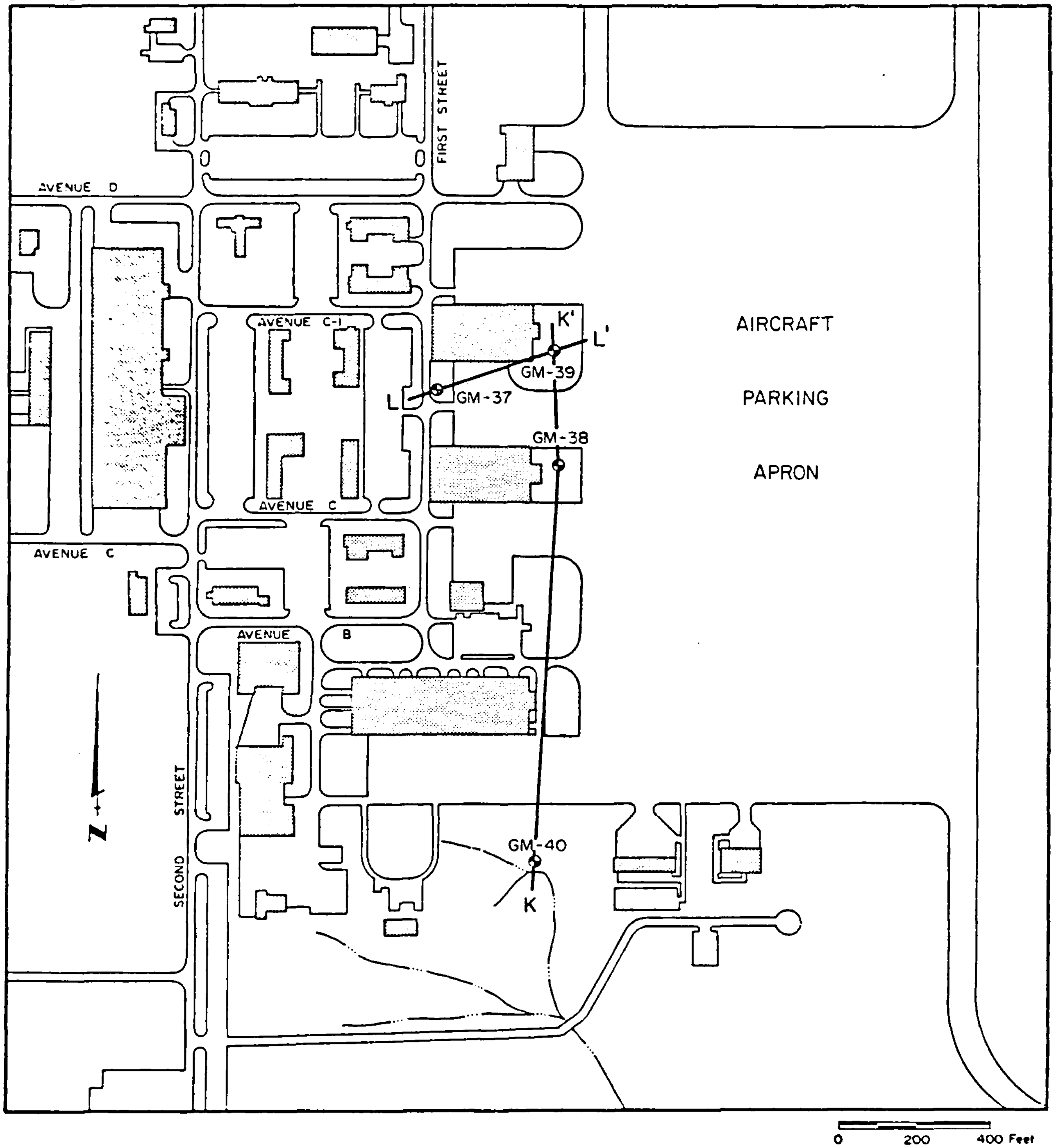


Figure 46. Locations of Inferred Geologic Cross-Sections K-K' and L-L', Flight Line Area, Myrtle Beach Air Force Base, South Carolina

FLIGHT LINE AREA

Hydrogeology

The Flight Line Area is located in the mid-southern portion of the base and is largely covered by paved parking aprons, roadways, and large buildings. Boreholes/monitor wells were installed within small, grass-covered areas, and encountered predominantly sand deposits (with a fairly high natural organic content) throughout drilling depths (about 15 feet below ground). At the GM-40 location, a 5-foot-thick clay layer was also present within a few feet of the land surface (see Figures 46 and 47).

The water table was generally encountered within 10 feet of ground level. Under lower water-level conditions, groundwater flow is generally to the south, probably toward and into a drainage alignment system located in this area (see Figure 48). However, as the water table rises, flow appears to reverse back toward the GM-37 and GM-38 locations. These trends may reflect the presence of the subsurface drains which exist beneath this area; i.e., under low water-level conditions, the drains are above the water table, but as water levels rise, the drains intercept the water table and exert an influence on groundwater flow patterns.

water table, and even lower levels of 1,2-trans-dichloroethylene (0.003 mg/l) and chlorobenzene (0.003 mg/l) within the deeper zone (06/83 analyses). Consequently, it appears that landfilling practices in these areas have resulted in only minor water-quality degradation by volatile organic compounds.

Inorganic compounds (12/82 and 06/83 analyses) were also within apparent natural levels in most of the monitor wells at this site. However, at the GM-46 monitoring location (the shallow downgradient well) specific conductance, and sulfate, bicarbonate, calcium, and potassium concentrations were elevated (06/83 analyses). It is likely that these parameters are emanating from landfill materials. Samples from the GM-45 monitor well (the deep downgradient well pair) showed significantly reduced levels of all of these constituents, suggesting that inorganic contaminants have remained mostly within the upper water table in this area.

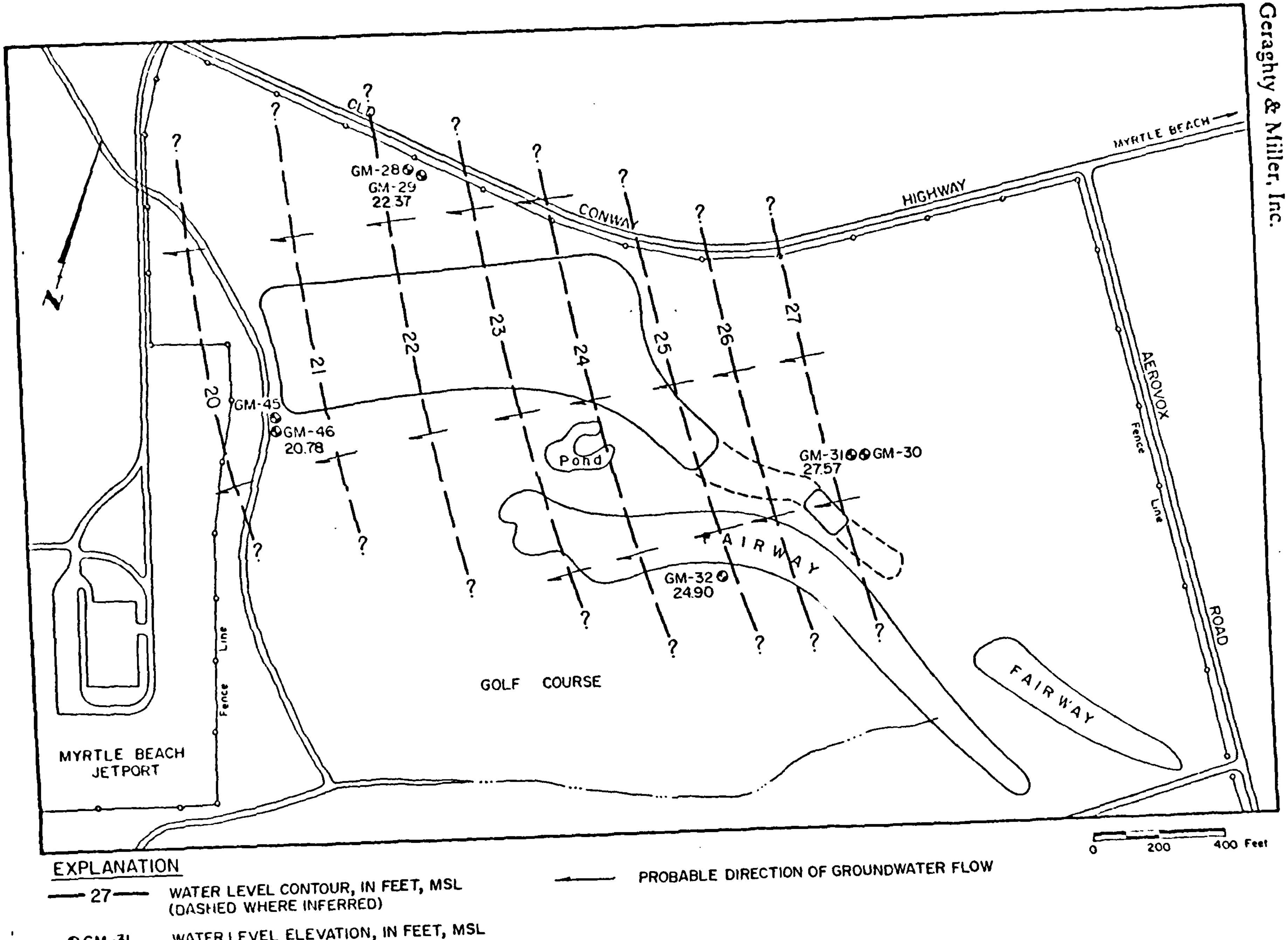


Figure 45. Inferred Shallow Groundwater Flow Patterns at Landfills #1 and #4, Myrtle Beach Air Force Base, South Carolina (based on 06/83 data)

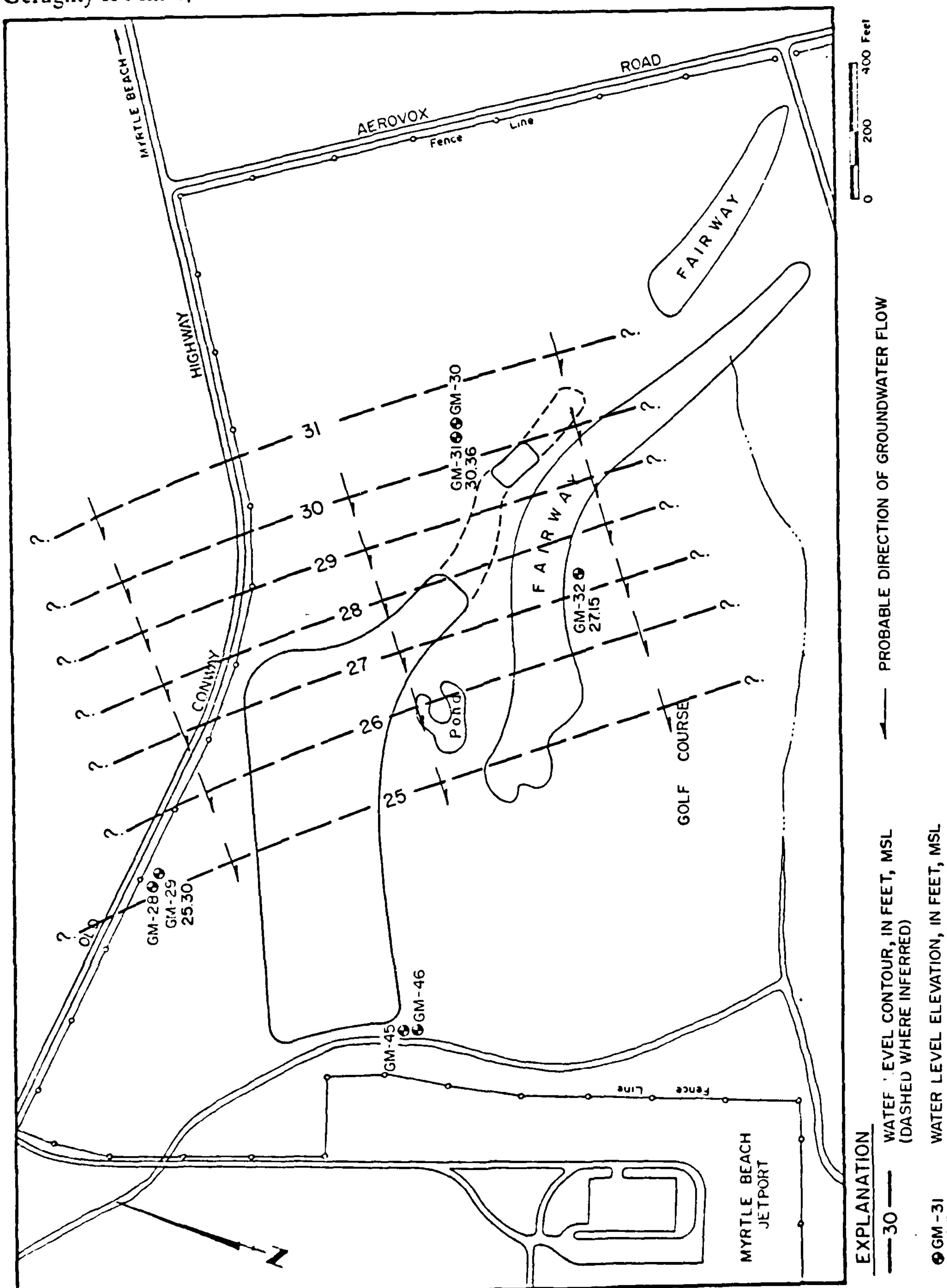


Figure 44. Inferred Shallow Groundwater Flow Patterns at Landfills #1 and #4, Myrtle Beach Air Force Base, South Carolina (based on 02/83 data)

direction of a drainage ditch that traverses the edge of this site. Groundwater flow patterns during relatively high and low water-level conditions are indicated in Figures 44 and 45, respectively.

Groundwater Quality

Landfill #1 was used from 1955 to 1960 for the trench burning and cover-type disposal of general refuse. Owing to air pollution restrictions during the active life of Landfill #4 (1968 to 1972), only trench and cover disposal of refuse was conducted at this site.

Chemical analyses of groundwater samples from shallow and deep monitor wells in these areas found TOX values always less than 0.09 mg/l and 0.04 mg/l, respectively (Appendix G, Part G-6). TOC levels were consistently higher in samples from shallow wells, averaging 21 mg/l versus 6 mg/l in deep wells; however, this trend is believed to represent natural conditions, probably reflecting the relatively greater abundance of organic material within the more shallow sediments. Analyses for volatile organic compounds conducted on the GM-46/GM-45 (shallow/deep) well pair, which is located hydraulically downgradient from both landfills, detected very low concentrations of benzene (0.006 mg/l) and toluene (0.006 mg/l) within the shallow

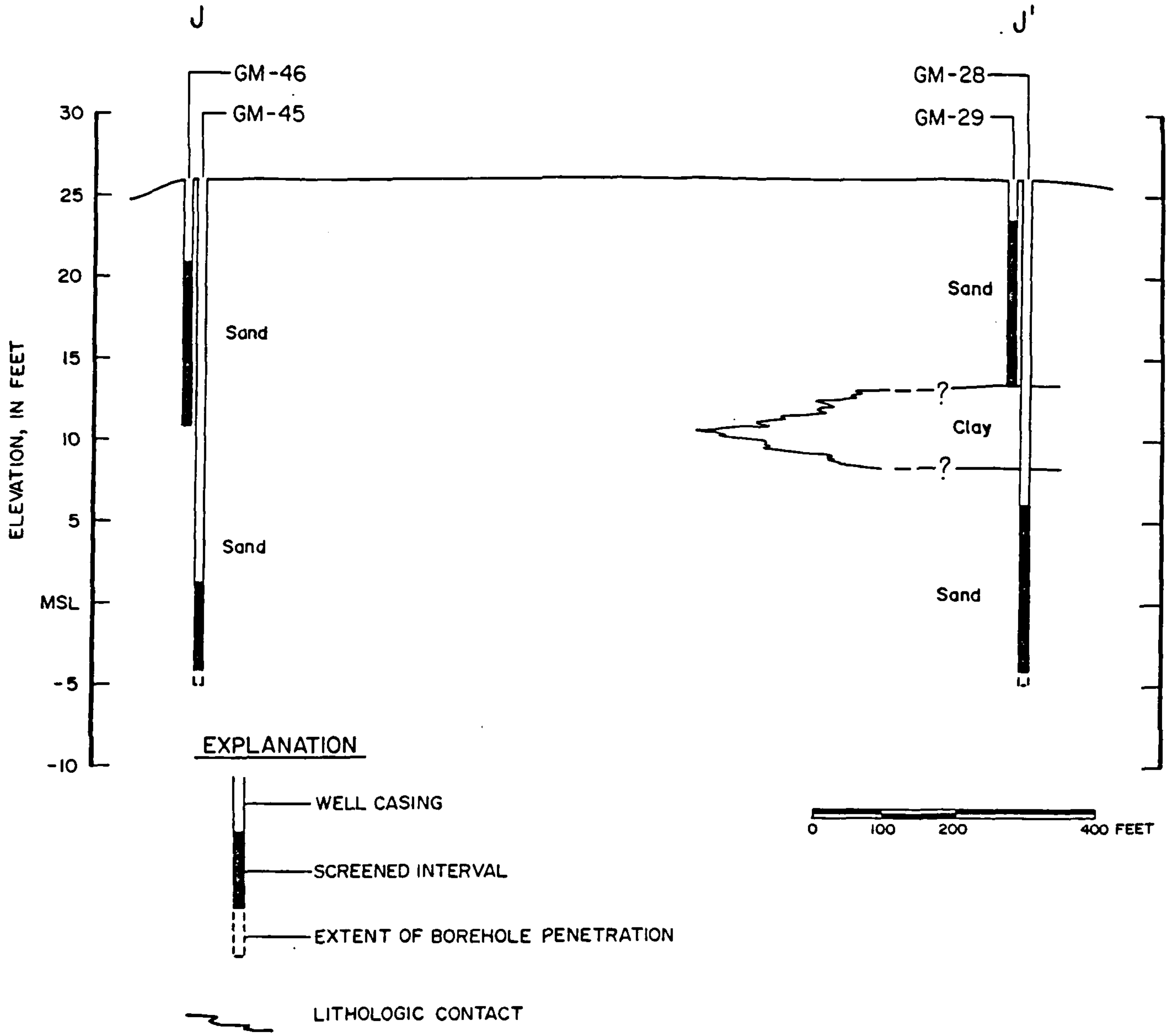


Figure 43. Inferred Geologic Cross-Section J-J', Landfills #1 and #4, Myrtle Beach Air Force Base, South Carolina

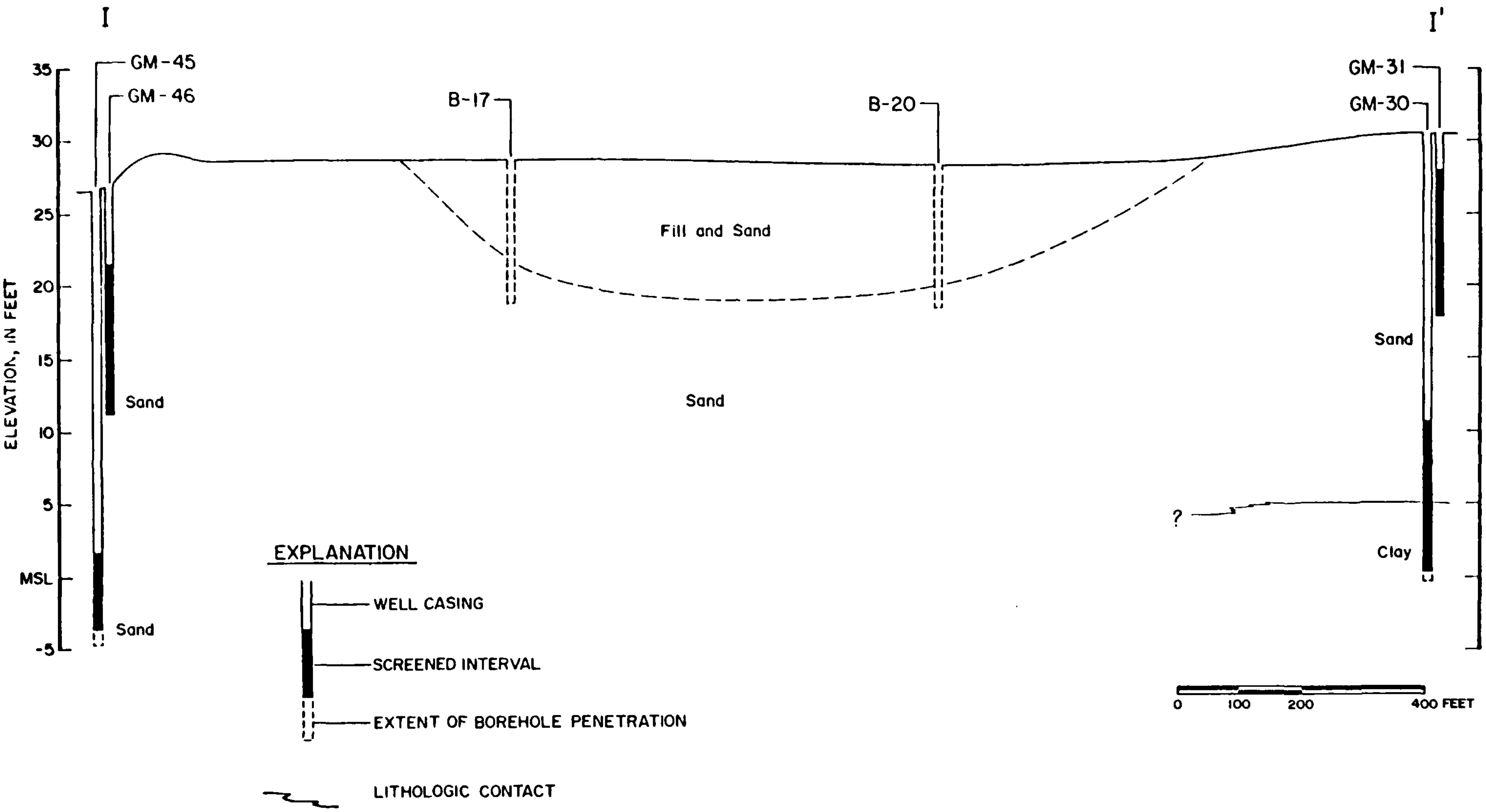


Figure 42. Inferred Geologic Cross-Section I-I', Landfills #1 and #4 Myrtle Beach Air Force Base, South Carolina

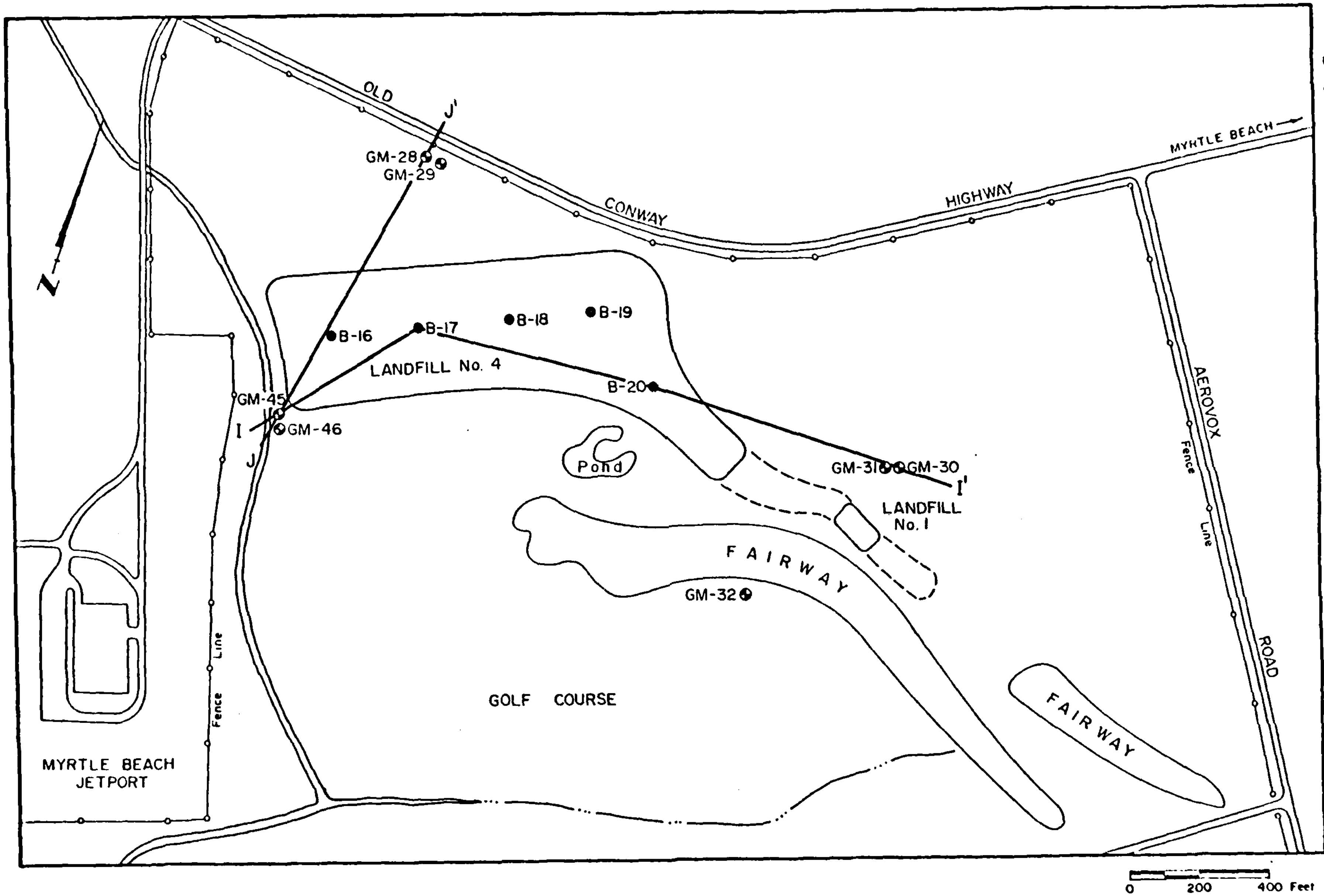


Figure 41. Locations of Inferred Geologic Cross-Sections I-I' and J-J', Landfills #1 and #4, Myrtle Beach Air Force Base, South Carolina

LANDFILLS #1 and #4

Hydrogeology

Landfills #1 and #4 are located in the far northeastern corner of the base, being bordered by a golf course to the south, and forest/underbrush-type vegetation on all other sides. Surficial and underlying sediments in the area consist mainly of sand-rich deposits which extend to depths of 30 feet or more. In general, shallow sands beneath the area (to depths of 10 to 15 feet) are brown colored and contain relatively greater abundances of natural organic material than the deeper, grey colored sands. Clay lenses are sometimes present and, at the GM-30 location, the sand is underlain by clay at a depth of about 25 feet. Fill and rubble are also present in the upper few feet of sediments within the immediate landfill area. Figures 41, 42, and 43, indicate geologic trends within this area.

Owing to the absence of clay confining layers, the water table is the only hydrogeologic unit encountered beneath this area (within the depths that were drilled). The water table was typically intercepted within 5 feet or less of the land surface, with flow (during both wet and dry monitoring periods) to the southwest, apparently in the volatile organic compounds (particularly as indicated by the 06/83 analyses) suggest that concentrations of fuel components within the water-table system have, over time, been greatly reduced; possible mechanisms include bio-degradation and periodic "flushing" during high water-level periods. Although no contaminant plumes are apparent, one could speculate that dissolved and/or separate-phase fuel components moved toward and discharged into the drain-age ditches (especially during high water-level periods), and were carried from the site by surface water runoff.

Analyses conducted on samples from deep monitor well GM-44, which is paired with GM-35, indicate nondetectable levels of all volatile organic compounds except 1,2-trans-dichloroethylene (0.001 mg/l). These results suggest that the clay layer confining the shallow artesian unit has effectively precluded the passage of organic compounds into the lower water-bearing zone (up to this point in time).

table and the artesian unit (see Table 7). The confining clay layer appears to be relatively thick, about 15 feet at GM-44, and is characterized by a low vertical permeability of about 7.6×10^{-8} cm/sec (see Table 6, sample GM-44). Consequently, there may be a fairly high degree of hydraulic separation between the water table and the shallow artesian unit.

Groundwater Quality

Sometime between 1963 and 1967, a 10,000-gallon jet fuel spill was reported to have occurred within the POL area. One could reasonably speculate that this material initially existed as a separate phase that floated on top of the water table. However, groundwater samples collected and analyzed at the time of this study found only low-level water-quality degradation by fuel-related organic compounds; TOX and TOC values were always below 0.04 mg/l and 14 mg/l, respectively (see Appendix G, Part G-5).

Analyses for specific volatile organic compounds conducted on samples from the GM-35 monitor well, which exhibited the highest TOX value (0.036 mg/l), indicate low concentrations of benzene, ethylbenzene, chlorobenzene, and toluene (see 02/83 and 06/83 analyses). Low levels of

Groundwater Quality

During 1977, a pumping test (30 feet deep/10 gpm) conducted near building 358 (within the Flight Line Area) supposedly encountered fuel-contaminated water throughout a 24-hour testing period. The chemical nature and quantity of contaminant were not documented at the time of the test; and, monitor wells installed during this investigation do not verify the reported conditions.

TOX values in all wells except GM-38 were 0.05 mg/l or less (Appendix G, Part 6-7). At the GM-38 location, where TOX values were relatively high (0.117 mg/l), analyses for volatile organic compounds found low levels of chloroform (0.005 mg/l) and 1,2-dichloroethane (0.012 mg/l) (02/83 analyses). TOC levels in this area are fairly high compared to other parts of the base, ranging from 15 to 35 mg/l. However, TOC concentrations are thought to be natural, probably reflecting the abundance of organic materials within shallow deposits.

Possible explanations for the difference in reported (1977) versus detected levels of fuel-type contamination include:

- Fuels have been removed from the system via the 1977 pump test, subsurface drain systems, high water-level "flushing" of shallow sediments, and biodegradation.

- Monitor wells failed to intercept the contaminant plume
- Initial reports did not accurately reflect subsurface conditions.

A more extensive investigation would be required to adequately refine these possibilities, though it is not recommended due to the apparent lack of significant levels of contamination shown by the IRP field study.

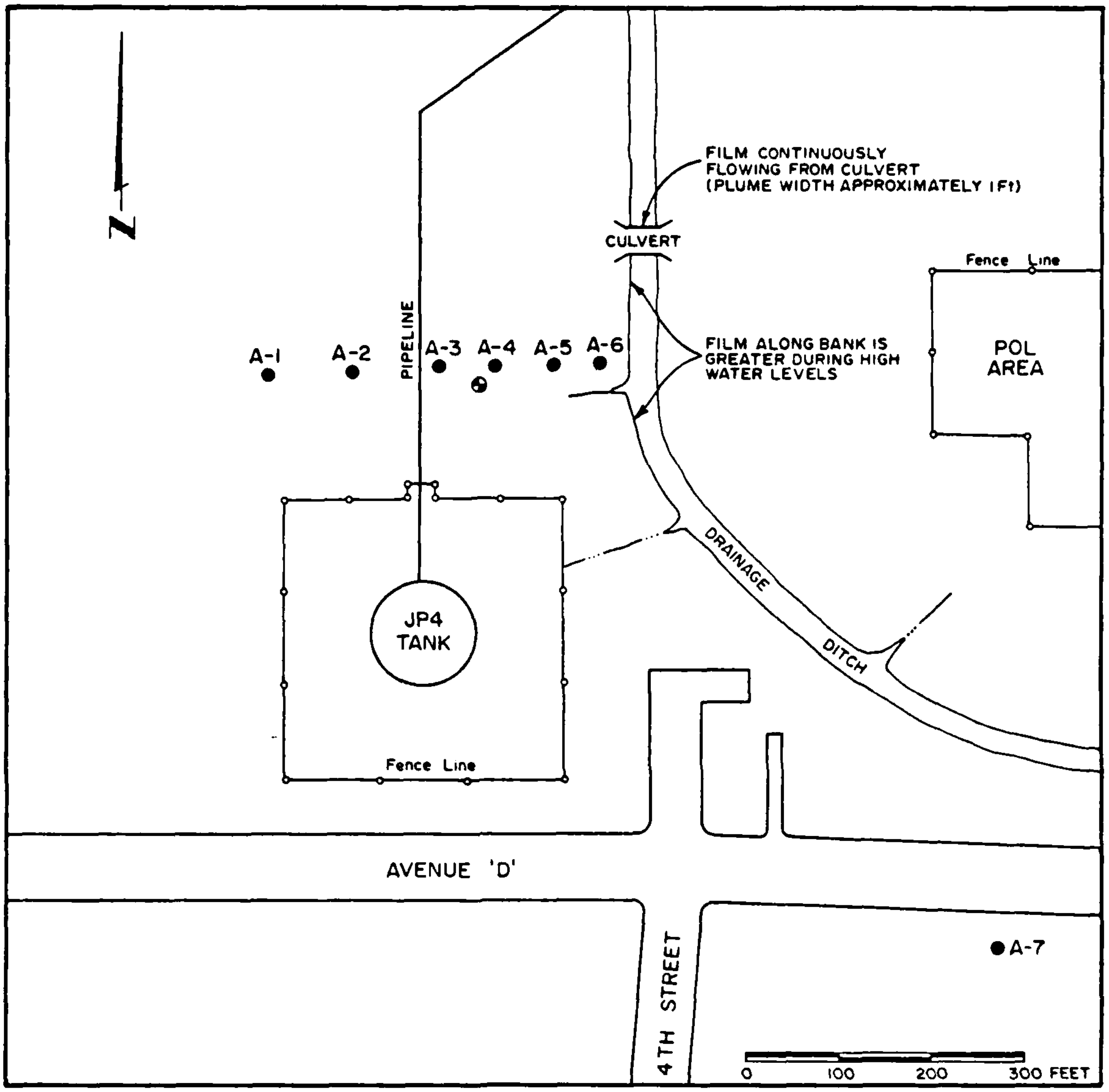
PIPE LINE SPILL AREA

The Pipeline Spill Area is located in the northwestern part of the base, being bordered by a large fuel storage tank to the south, and trees and thick underbrush on all other sides. No drilling, soil sampling, or groundwater monitoring was conducted at the Pipeline Area during this investigation. However, based on boring data gathered during a recent study (Soil & Materials Engineers (S&ME), Inc., 1982), the site is underlain by alternating sand-rich and clay-rich layers, to depths of at least 25 feet. Surficial deposits range from sandy clay to clayey sand composition and the water table lies within a few feet of the land surface. Groundwater flow is probably mainly to the east, in the direction of a deeply incised drainage ditch located about 150 feet from the spill area.

The spill, which occurred in 1981, is reported to have accidently discharged roughly 124,000 gallons of jet fuel onto the ground. About 24,000 gallons of fuel have been recovered and the rest remains within shallow sediments or has migrated toward and discharged into drainage ditches; a visible sheen on top of water pooled in the nearby ditch suggests that such discharge is occurring (especially during high water-level conditions).

Inspection of an existing (5-inch-diameter) monitor well located to the east, and hydraulically downgradient of the Spill Area indicates that the water table, at least in this area, is topped by a layer of jet fuel measuring more than one foot in thickness. Hand-auger work confirmed the presence of high-level fuel contamination within shallow sediments, but found a much thinner layer of fuel within the open boreholes, generally measuring less than an inch in thickness (see Figure 49). The borehole measurements are believed to more accurately reflect fuel layer conditions; greater thickness of fuel within the monitor well may have occurred as a result of groundwater withdrawals, which could have created a localized cone of depression that would tend to accumulate lighter-than-water fluids.

Water quality analyses conducted during the prior investigation (S&ME, Inc., 1982) detected fairly low levels of jet fuel (less than 0.4 mg/l) in groundwater samples collected beneath the fuel layer. This trend suggests that the vertical migration of fuel contaminants is limited, relative to lateral movement. Two possible reasons for slow vertical mixing are that fuel is lighter than water and tends to remain at or near the top of the water table, and lower clay-rich units may be inhibiting downward vertical movement.



EXPLANATION

● HAND AUGERED BORING

⊕ EXISTING 4-INCH WELL

BORING NUMBER	PRODUCT THICKNESS (Feet)	CONDUCTIVITY (μmhos)
A-1	.00	250
A-2	.01	130
A-3	.01	500
A-4	.04	100
A-5	<.01	100
A-6	<.01	250
A-7	.00	300
WELL	1.04	0

Figure 49. Locations of Hand-Augered Borings Used to Measure Fuel Layer Thicknesses in the Pipeline Spill Area, Myrtle Beach Air Force Base, South Carolina

Results of the surface geophysical surveys conducted in the Pipeline Area do indicate the presence of a high-conductivity plume (or subsurface zone) that appears to emanate from the approximate location of the spill, and decreases with distance from this source (see Figures 50 and 51, and Appendix D). However, it should be noted that jet fuel is characterized by a very low conductivity (relative to groundwater); and, there are some major, unresolved questions regarding the physical phenomena responsible for these observed trends. Consequently, it is very possible that Figures 50 and 51 do not accurately convey existing jet fuel plume conditions, and further study is recommended to verify the true extent of jet fuel contamination beneath the Pipeline Spill Area; such studies are particularly important if remedial measures are to be designed and implemented.

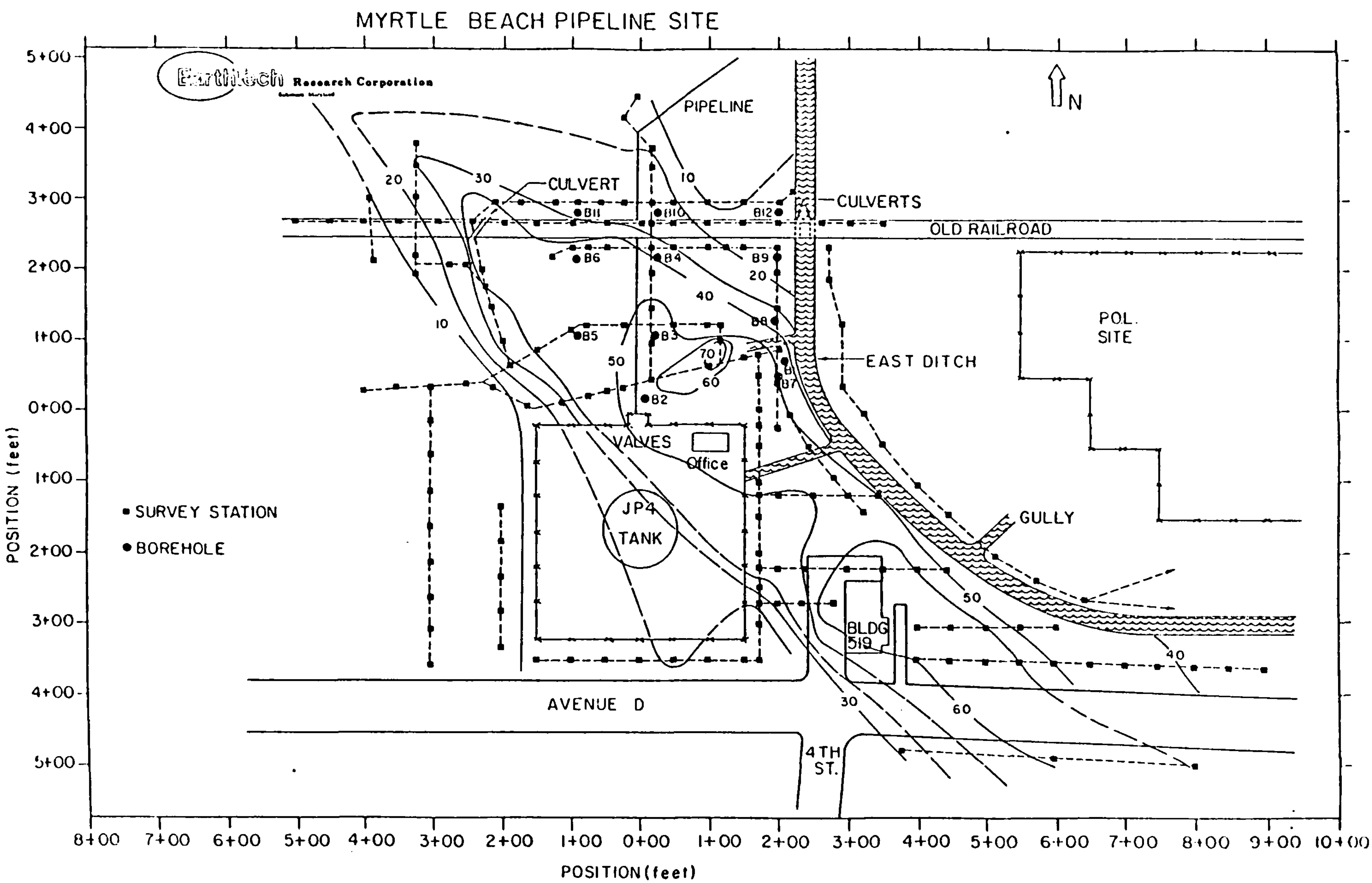


Figure 50. Contour Map of Conductivity Measurements (millimhos/meter) in the Pipeline Spill Area, Myrtle Beach Air Force Base, South Carolina (representing bulk conductivities over a depth of about 15 feet).

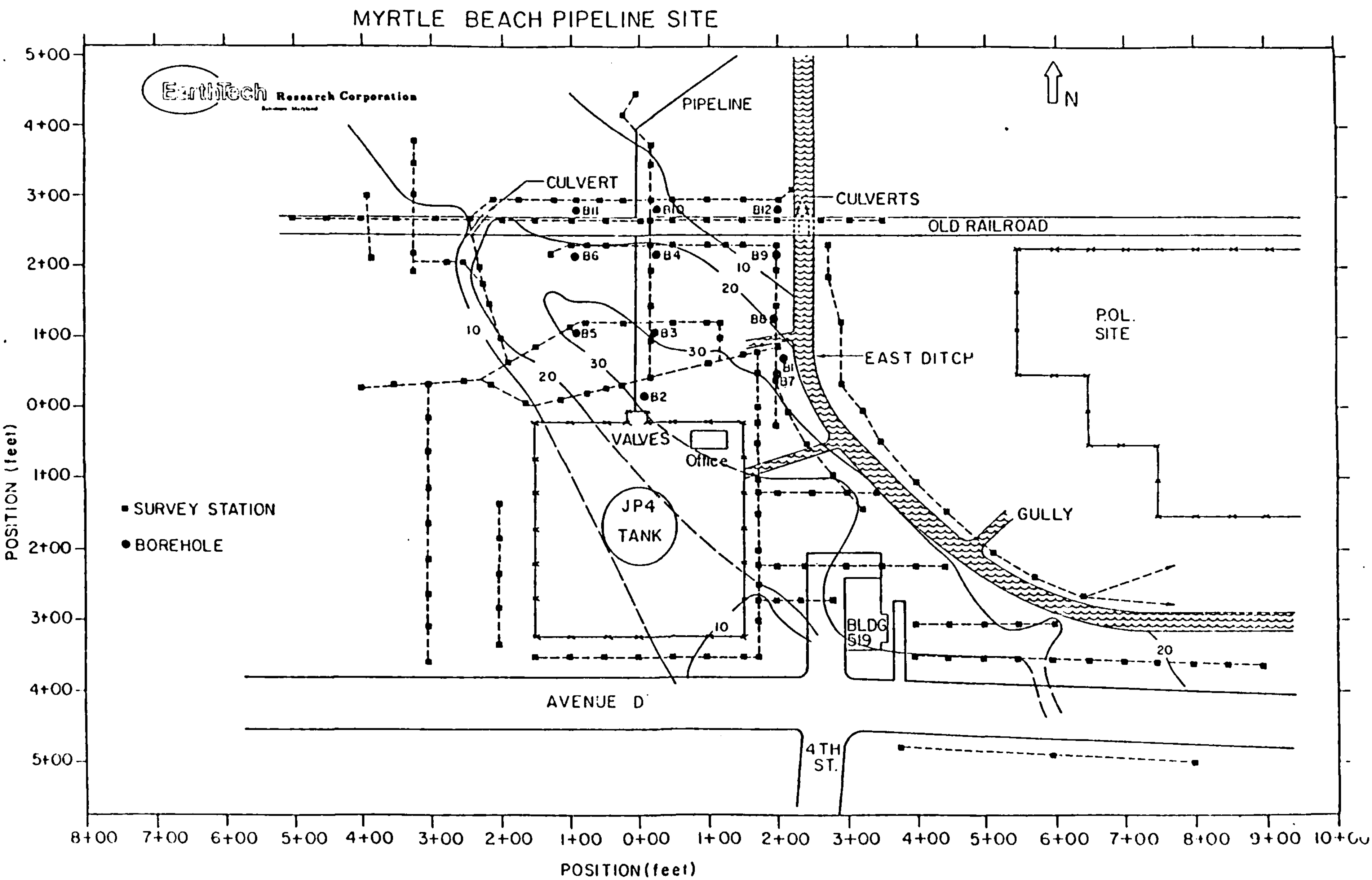


Figure 51. Contour Map of Conductivity Measurements (millimhos/meter) in the Pipeline Spill Area of Myrtle Beach Air Force Base, South Carolina (representing bulk conductivities over a depth of about 5 feet).

SIGNIFICANCE OF FINDINGS

Results of drilling, soil sampling, and groundwater monitoring programs conducted at seven of the potential contaminant source areas (i.e., all areas except the Pipeline Spill Area) have served to identify a number of important hydrogeologic trends that pertain to all seven sites. These trends, and their significance, are collectively discussed below. The significance of trends observed in the Pipeline Spill Area will be presented in a separate section that follows these discussions.

FIRE TRAINING AREAS #1 AND #2, LANDFILL #3/WEATHERING PIT #2, FIRE TRAINING AREA #3, WEATHERING PIT #1, POL AREA, LANDFILLS #1 AND #4, AND FLIGHTLINE AREA

1) Practices conducted at all of the sites have resulted in varying degrees of low-level groundwater contamination by one or more volatile organic compounds; water-quality alteration by inorganic compounds is noticeable (although fairly minor) in areas hydraulically downgradient from landfills. In waters used for drinking supplies, even minute quantities of organic-type contaminants are undesirable (see Table 8, Ambient Water Quality Criteria, Human Health); however, the shallow water-table system does not appear to be utilized for drinking water supplies in the vicinity of any of the identified source areas.

TABLE 8.

AMBIENT WATER QUALITY CRITERIA (AWQC) FOR VOLATILE ORGANIC CHEMICALS ANALYZED IN GROUNDWATER FROM MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA
(all values in ug/l (mg/lx1000) unless otherwise specified)

Organic Compound	Saltwater	Freshwater	Human Health*
Benzene	5,100[a]	5,300[a]	6.6, 0.66, 0.066
Toluene	6,300[a] 5,000[b]	17,500[a]	14,300
Ethyl benzene	430[a]	32,000[a]	1,400
Chloroform	Insufficient Data	28,900[a] 1,240[b]	1.9, 0.19, 0.019
Chlorobenzene	160[a] 129[b]	250[a]	7.2 ng/l, 0.72ng/l 0.072 ng/l
Methylene Chloride (Chloromethane)	12,000[a] 6,400[b]	11,000[a]	1.9, 0.19, 0.019
Dichloroethylenes	224,000[a]	11,600[a]	0.33, 0.033, 0.0033
Chloroethane	NC	NC	NC
1,2-Dichloroethane	113,000[a]	118,000[a] 20,000[b]	9.4, 0.94, 0.094
1,1-Dichloroethane	NC	NC	NC

AWQC source: Criteria and Standards Division, Office of Water Planning and Standards, U.S. Environmental Protection Agency; presented in November 28, 1980, Federal Register, Vol. 45, No. 231.

* Health criteria are for human consumption of water and aquatic organisms; three successively lower values correspond to 10^{-5}, 10^{-6}, and 10^{-7} life time cancer risks.

a - Acute toxicity for aquatic organisms
b - Chronic toxicity for aquatic organisms
NC - No criteria listed for aquatic organisms

There are no specific rules or regulations specifying acceptable levels of volatile organic compounds (of the types found) in groundwater or surface waters. However, Water Quality Criteria presented in Table 8 do list chronic and/or acute toxicity levels for freshwater aquatic life. Concentrations of detected volatile organic compounds (which are included in the AWQC list) were generally well below one or both of these limits; chlorobenzene levels at Fire Training Area #3, sample GM-19, did exceed AWQC levels. By the time groundwater reaches surface-water bodies (and aquatic life), it is likely that concentrations of volatile organics will be even lower (relative to levels observed within the water table beneath the sites) as a result of various environmental attenuation mechanisms; such mechanisms include dilution, biodegradation, and sorption.

2) Sites having relatively clay-rich surficial sediments (e.g., Weathering Pit #1 and Fire Training Area #3) tend to have higher concentrations of organic compounds than sites with relatively sand-rich surficial sediments (e.g., Fire Training Areas #1 and #2, POL area, Landfills #1 and #4, and the Flight Line Area). This may simply reflect differences in initial water-quality conditions resulting

from the various practices; however, the observed trend could also reflect the manner in which different sediments accommodate organic contaminants. Possible differences include:

- Clays may be less readily "flushed" during high water-level periods
- Contaminants may be less mobile, and thus remain more concentrated in clay sediments
- Increased pore space and aeration in sand deposits may allow volatile organics to degas and escape more readily
- Biodegradation of organic compounds may occur less rapidly in clays than in sands.

3) Contaminants (both organic and inorganic) are most concentrated within the upper water table, and generally do not appear to have appreciably degraded the quality of groundwater within the lower water table or the shallow artesian unit. Possible explanations include:

- Confining clay layers reduce or prevent vertical migration of contaminants into lower zones
- Vertical hydraulic gradients became negligible or reversed in some areas (during dry periods), thus periodically favoring upward movement of groundwater and dissolved constituents.

4) Distinguishable "plumes" of contamination are not generally observed at the identified source areas, because:

- Drainage ditches exert a strong influence over shallow groundwater flow patterns and thus, often tend to intercept contaminants before they have moved an appreciable distance from the source area

- It is likely that most source contaminants were introduced into the subsurface as pulses rather than at a steady rate and, therefore, may travel within the shallow groundwater system as slugs, rather than a well defined plume

- Flow patterns beneath several of the sites are substantially altered under varied weather conditions, resulting in erratic contaminant migration

- Contaminants within potential plume bodies may be periodically or continually removed as a result of high water-level flushing and/or relatively rapid environmental attenuation within shallow deposits.

5) Major groundwater supply aquifers beneath the Myrtle Beach area are not likely to be affected by shallow groundwater contamination at MBAFB because:

- Important aquifers are artesian, and are overlain by fairly extensive confining clay units

- The artesian aquifers are recharged mostly in outcrop areas which lie inland from MBAFB

- Water-quality data indicate that contaminants have not moved appreciably downward within the shallow deposits.

6) The quality of water from shallow domestic wells in the vicinity of MBAFB (if such wells exist) is probably not threatened by the identified contaminant source areas, since contaminants are mostly intercepted by drainage ditches that discharge to the Intracoastal Waterway and the Atlantic

Ocean, and since the data suggest that the extent of lateral migration within shallow water-bearing deposits is limited.

by inorganic parameters is also apparent. Groundwater monitoring (Alternative 3) utilizing hydraulically down-gradient monitor wells is proposed at all of these sites; wells to be used in Alternative 3 monitoring are indicated in Table 10. The primary objective of this proposed program is to better define the tendency for contaminants to migrate vertically downward into the lower water table and shallow artesian unit; this is why shallow/deep well pairs have been selected to identify water-quality trends. In addition, monitoring groundwater quality at these selected locations could provide advanced warning of high-level contaminant plumes that could eventually discharge into surface-water bodies, if in fact, such plumes exist.

Monitoring of surface-water quality (Alternative 4) in drainage ditches adjacent to Landfill #3/Weathering Pit #2 and Landfills #1 and #4 (3 sampling locations in all) is also recommended (see Table 10); ditches near the other sites listed above are relatively shallow and contain appreciable quantities of surface water only during wet seasons. Results of this monitoring should provide important information about the extent of surface-water degradation by adjacent contaminant source areas; and, may also provide insights regarding the extent to which contaminant concentrations are reduced by attenuating mechanisms operating within receiving surface-water bodies (e.g., dilution, sorption, biodegradation, etc.).

situation, including the fact that another party has studied this same spill area. Alternative 2, collection and treatment of contaminated groundwater, has not been recommended at any of the sites at this time, but is a possible remedial measure that could be utilized if groundwater and/or surface-water monitoring data (Alternatives 3 and 4) indicate a need for additional environmental protection.

Specific details of the recommended remedial measure/ alternative action plans to be conducted at the identified sites are presented in the following sections. Owing to the similarity in hydrogeologic conditions and corresponding proposed alternative actions at Fire Training Areas #1 and #2, Landfill #3/Weathering Pit #2, Fire Training Area #3, Weathering Pit #1, POL Fuel Spill Area, and Landfills #1 and #4, these sites will be discussed collectively. The remaining two sites, i.e., Flight Line and Pipeline Spill Areas, will be discussed separately.

Fire Training Areas #1 and #2,
Landfill #3/Weathering Pit #2,
Fire Training Area #3,
Weathering Pit #1,
POL Fuel Spill Area, and
Landfills #1 and #4.

These sites are all characterized by low-level groundwater contamination by one or more organic compounds; at landfills #1, #3, and #4, some water-quality alteration

Alternatives 6, 7, and 8, establish and/or maintain proper vegetation cover, prohibit shallow wells and restrict deep wells, and restrict gardening and certain land uses in the vicinity of identified source areas. Although these measures do not attempt to quantify existing and future impacts, they do establish common-sense safeguards that could reduce the potential for environmental degradation and/or human contact with contaminants. Alternative 6 is already a routine practice at many of the sites and simply involves maintaining existing vegetation, generally grass. Alternatives 7 and 8 should also be fairly easy to implement, possibly by requiring pre-authorization permits for well constructions and land uses in the vicinity of each site.

As can be seen in Table 9, Alternatives 3, 5, 6, 7, and 8 are recommended in almost every case, and Alternative 4 has been proposed at sites where drainage ditches contain surface water throughout much of the year. Recommendation of Alternative 1, removal or in-situ treatment of contaminant source materials, was considered for the Pipeline Area, where a recent (1981) and major (124,000 gallons) fuel spill occurred, and a high degree of contamination is apparent within the shallow system. This recommendation is not being made at this time, however, due to the complexity of the extensively developed) aquifer systems. As noted earlier in this report, such wells can serve as conduits for contaminant passage through otherwise impervious clay layers. Consequently, it is very important that these wells (if any exist) be located and properly plugged; for, they could create a third, and relatively less acceptable, pathway by which contaminated groundwater could exit the shallow system. Possible approaches for accomplishing Alternative 5 include: searching out available well records from MBAFB files, local and State agencies, etc.; contacts with local drillers (particularly the older ones) who may have first hand or indirect knowledge of wells installed within base boundaries; review old maps (pre MBAFB) to locate old dwellings which may have utilized shallow and/or deep wells; inspect shallow water-level data for erratic groundwater flow patterns that could reflect discharge into buried installations (e.g., erratic flow patterns beneath the Flight Line Area should be accounted for); conduct visual field inspections for obvious well remnants (e.g., casing stick-ups, cement well slabs); conduct ground-penetrating field inspections for well remnants using metal detecting devices (remnants include metal casing, piping from the well to the receiving area, etc.).

It is recommended that surface-water monitoring be conducted quarterly during the first year and semi-annually during the four subsequent years (5 year program). Parameters to be analyzed during the first and subsequent years, as well as the procedures to be followed if apparent increases occur, are the same as those listed for groundwater monitoring. Efforts should be made to collect all surface-water samples during relatively low flow conditions so that the quality of these fluids will mainly represent shallow groundwater discharge (i.e., base flow) and not surface runoff or overland flow. If, after the designated monitoring period, no detrimental water-quality conditions are observed, surface-water monitoring could be reduced or eliminated. However, because drainage ditches probably represent the main avenue for groundwater and contaminant departure from the base, it may be desirable to continue monitoring indefinitely to insure that past and future MBAFB practices do not cause unacceptable degradation of surface water leaving the base.

Alternative 5, field and records inspection to locate improperly abandoned or poorly constructed wells, is another important alternative action, for it could serve to avert deterioration of water quality within deeper (and more specifically: the relationships between volatile organic compounds and TOX and TOC levels, and the relationships between concentrations of individual dissolved constituents and TDS and SC levels. Having established these trends, the number of parameters analyzed in annual samples collected during the four subsequent years can be reduced to include only the main contamination indicators, namely: pH, SC, TOC, TOX, and TDS. If over the course of annual monitoring, concentrations of indicator parameters show a significant increase, a repeat sampling and analysis should first be conducted (on the sample in question) to verify the condition; and, if increases have occurred, at least one set of analyses for the full list of parameters should be performed to determine which specific constituents are responsible for increased indicator levels. Depending on the results of such analyses, additional remedial measures might be warranted. If analytical results, after five years of monitoring, indicate that contaminant and/or indicator concentrations have remained essentially unchanged, or have become reduced, groundwater monitoring could be discontinued. This, of course, would be at the discretion of Air Force personnel and State and/or Federal agencies that may be involved.

quantifying the extent of existing water-quality impacts logically must focus on the primary contaminant-receiving bodies. This basically involves: Alternative 4, monitoring surface-water quality within main drainage ditches located hydraulically downgradient from identified source areas; and Alternative 3, monitoring shallow and deep groundwater quality trends to assess the extent of contaminant migration into underlying units. In addition to documenting the extent of downward contaminant movement, the latter measure, which would utilize well hydraulically downgradient from the source areas, may also provide advance warning of potential surface-water quality impacts that could result from discharges of contaminated groundwater.

Where recommended, it is proposed that groundwater monitoring be conducted on a quarterly basis during the first year and semi-annually during the four subsequent years (5-year program). Parameters to be analyzed in first year samplings should include: pH, specific conductivity (SC), total organic carbon (TOC), total organic halides (TOX), volatile organics (GC scan), total dissolved solids (TDS), sulfate, chloride, bicarbonate, calcium, magenesium, sodium, potassium, iron, and manganese. The first year data should then be evaluated to determine important chemical trends

TABLE 9.
RECOMMENDED REMEDIAL MEASURES/ALTERNATIVE ACTIONS TO BE PERFORMED AT IDENTIFIED SOURCE AREAS WITHIN MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA

Identified Potential Source Area	Recommended Remedial Measures/ Alternative Actions*							
	1	2	3	4	5	6	7	8
Fire Training Areas #1 and #2			X		X	X	X	X
Landfill #3/ Weathering Pit #2			X	X	X	X	X	X
Fire Training Area #3			X		X	X	X	X
Weathering Pit #1			X		X	X	X	X
POL Fuel Spill Area			X		X	X	X	X
Landfills #1 and #4			X	X	X	X	X	X
Flight Line Area				X	X	X	X	X
Pipe Line Spill Area			X	X	X	X	X	X

*Subject to change depending on results of groundwater and surface-water monitoring.

Alternative References:

1) Removal or in-situ treatment of contaminant source materials
2) Intercept and treat contaminated groundwater
3) Monitor downgradient and upgradient groundwater quality
4) Monitor surface-water quality in nearby drainage ditches
5) Conduct thorough area-of-review for improperly abandoned on-base wells
6) Establish and/or maintain vegetation cover
7) Prohibit installation of shallow wells and regulate design and construction of deep wells
8) Restrict land uses which could increase the potential for contact with contaminants in affected areas. (The actual restrictions would depend upon the intended use, the nature of the land area and the contaminants present, and only can be determined on a specific case by case base.)

RECOMMENDATIONS

Overview

In general, the ultimate objective of the remedial measures/alternative actions program is to implement the necessary measures to insure that existing and potential water-quality conditions do not endanger human health or the environment. A summary of recommended measures to be conducted at each of the identified sites is presented in Table 9. Detailed discussions of the rationale behind these recommendations are as follows.

A logical first step toward achieving the primary objective (which has been partially completed as a result of this study) is to define hydrogeologic conditions (e.g., groundwater flow, contaminant migration, water-quality trends, source-area relationships, etc.) in order to quantify existing impacts and reasonably predict probable future impacts. Contaminants beneath sites investigated at MBAFB are confined mostly to the upper water table, from which flow appears to be primarily toward drainage ditches, but which may also lose some quantity of fluids to underlying units. Therefore, monitoring strategies aimed at further

Alternatives 1 and 2 (i.e., remove or treat contaminant source materials and intercept and treat contaminated groundwater) are action-oriented measures that are used at sites where contaminant source materials are abundant or remain concentrated within shallow sediments. Alternatives 3 and 4 are more passive techniques that serve mainly to monitor trends in existing water quality; indications of increasing degradation could trigger a need to utilize Alternatives 1 or 2. Alternatives 5 through 8 represent general management tools that could be conducted at most sites to help to avert possible hazards, and to further define and minimize existing and potential water-quality impacts.

required, remedial measures/alternative actions could include any or all of the following:

1) Removal or in-situ treatment of contaminant source material(s) (e.g., product fluids, solid wastes, severely contaminated soils).

2) Intercept flow of contaminated groundwater via subsurface drains, ditches, or shallow well systems, and perform any treatments that may be needed to comply with surface water discharge restrictions.

3) Monitor the water table and deeper water-bearing units (to depths of ±30 feet) at selected locations hydraulically downgradient and upgradient from identified source areas to document any significant changes in groundwater quality.

4) Monitor important drainage ditch systems at selected locations hydraulically downgradient from identified source areas to detect adverse impacts to surface water quality, if such impacts exist.

5) Conduct thorough field and records inspections to locate abandoned wells that may be situated near identified source areas, and take necessary steps to insure that such wells are not serving as conduits for contaminant passage into deeper aquifers.

6) Establish and/or maintain grass or other suitable vegetation over identified source areas to stabilize soils and to reduce the potential for human contact with contaminants.

7) Prohibit the installation of shallow domestic wells and require that deep wells be designed not to transmit shallow groundwater in the vicinity of identified source areas.

8) Restrict gardening and certain land uses in areas that are, or could potentially become, affected by shallow contamination, to reduce the potential for skin contact and/or ingestion of contaminants.

REMEDIAL MEASURES/ALTERNATIVE ACTIONS

ALTERNATIVES

At all of the sites investigated, groundwater contaminants are largely confined to the upper portion of the water-table aquifer (5 to 15 foot depths), with only minor water-quality degradation apparent in the lower water table and the shallow artesian unit (roughly 20- to 35- foot depths). These conditions permit groundwater flow, as well as contaminant migration, to be controlled with relative ease using moderately deep drainage ditches or shallow well systems. In addition, the water-table aquifer does not serve as an important local source of water supply. Consequently, some of the more elaborate remedial measures that can be used to abate contaminant related problems (e.g., encapsulation, capping, chemical fixation, etc.) are probably not warranted at MBAFB, because relatively simple and less expensive methods can be utilized to prevent adverse impacts to human health and the environment.

The alternative remedial measures considered include those judged to be potentially cost-effective in accomplishing reasonable groundwater management goals. Depending on the degree of environmental protection that may be water-levels, when the water table probably rises to near-ground level and the fuel layer could become exposed at the land surface; i.e., fuel is "flushed" from the shallow system. It should be noted that there was no apparent explosive hazard from JP-4 vapors at the pipeline spill area during the IRP field investigation.

Over time, it is probable that the quantity of fuel within the shallow system will become reduced as a result of periodic "flushing", lateral discharge to drainage ditches, biodegradation, volatilization, and degassing. However, given the large volume of fuel that was spilled, these processes could take a long time to effectively cleanse the system, and potential impacts in the meantime may be unacceptable to the Air Force, regulators, or other parties that might become involved.

PIPELINE SPILL AREA

The geology and shallow hydrology in the Pipeline Spill Area is similar to that of other sites in the northwest part of the base, and several of the important findings noted earlier (findings 3, 5, and 6) are also thought to apply to this site. The main exceptions (findings 1, 2, and 4) reflect differences in the extent of contamination, in that, other sites experienced low-level water-quality degradation by organic compounds, whereas, the Pipeline Area (at least within shallow sediments) has become severely impacted by a recent (1981) fuel spill. As a result, fuel is sufficiently concentrated to form a separate phase that floats on top of the water table, and attenuating mechanisms within shallow sediments have probably been overwhelmed (at this point in time). In addition, it is likely that a plume of dissolved organic contaminants has formed below and around the floating fuel itself.

Aside from degrading the quality of surface water upon entering the nearby drainage ditch, the concentrated fuel layer, which can lie within only a few feet of the land surface, could represent a possible fire hazard. The potential for surface-water degradation and the hazard of fire may increase significantly during periods of prolonged high

TABLE 10
MONITOR WELLS AND DRAINAGE DITCHES TO BE INCLUDED IN THE PROPOSED WATER-QUALITY MONITORING PROGRAM AT MYRTLE BEACH AIR FORCE BASE, SOUTH CAROLINA

Identified Contaminant Source Area	Alternative 3 Groundwater Monitoring Locations	Alternative 4 Surface Water Monitoring Locations
Fire Training Areas #1 and #2	GM-5/GM-6, GM-4	none
Landfill #3/ Weathering Pit #2	GM-14/GM-41 GM-17	west ditch south ditch
Fire Training Area #3	GM-19/GM-42 GM-21/GM-22	none
Weathering Pit #1	GM-24/GM-43 GM-26/GM-27	none
POL Area	GM-35/GM-44	none
Landfills #1 and #4	GM-46/GM-45	southeast ditch
Flight Line Area	none	south ditch
Pipeline Spill Area	(6 wells in all)*	east ditch
TOTALS	24	5

*It is recommended that at least three shallow/deep well pairs, two downgradient and one upgradient, be installed to monitor groundwater quality at this site.

GM-#/GM-# corresponds to shallow/deep monitor well pair.

In addition to water-quality monitoring, Alternatives 5, 6, 7, and 8 (i.e., area-of-review, establish and/or maintain vegetation cover, prohibit shallow wells and restrict deep wells, and restrict gardening and certain land uses) are recommended at each of these sites. Barring the presence of improperly abandoned wells that might be discovered as a result of Alternative 5, it is not anticipated that any of these measures will involve a major level of effort; Alternatives 7 and 8 can be accomplished by requiring pre-authorization permits for activities to be conducted near identified source areas, and the Alternative 6 task of establishing vegetation cover is necessary mainly at Weathering Pit #2.

Because initial contaminant source materials no longer appear to be concentrated at these sites, the need to implement Alternative 1 clean-up procedures is not anticipated. Also, because groundwater contaminants are present beneath these sites at fairly low levels, it is unlikely that Alternative 2 (collection and treatment) will be required unless water-quality monitoring (Alternatives 3 and/or 4) demonstrates the need for increased degrees of environmental protection.

Flight Line Area

The Flight Line Area differs from most other sites in that no groundwater monitoring (Alternative 3) is recommended. This is because monitor wells failed to intercept the reported fuel plume and groundwater flow patterns beneath this site are very erratic. Consequently, monitoring data from existing wells would permit only limited interpretations and is probably not meaningful. It is, however, recommended that the drainage ditch to the south of the Flight Line be monitored (Alternative 4) because this surface-water body probably receives much of the shallow groundwater discharge emanating from beneath the Flight Line Area.

As with the other sites, Alternatives 5, 6, 7, and 8 are recommended in the Flight Line Area as an added precaution against environmental and human health impacts that could occur if the reported fuel plume does, in fact, exist. Barring the presence of improperly abandoned wells (Alternative 5), these measures probably will require a fairly low level of effort. However, groundwater flow beneath this area is erratic, and it is important that Alternative 5 be pursued to the point of identifying the cause for observed flow patterns.

Pipeline Spill Area

The Pipeline Spill Area is in a different category from all the other sites because shallow sediments beneath this area have become extremely contaminated as a result of a recent (1981) fuel spill. Unlike other sites, a layer of fuel is observed on top of the water table and visible discharge of fuel (and/or related compounds) is seen entering the nearby drainage ditch. Recommendation of Alternative 1, removal or in-situ treatment of contaminant source materials, was considered for the Pipeline Area. This recommendation is not being made at this time, however, due to the complexity of the situation, including the fact that another party has studied this same spill area.

Groundwater and surface-water monitoring (Alternatives 3 and 4) are recommended at the Pipeline Area in order to determine the extent of existing water-quality impacts and to document improvements in water quality, over time. Surface-water monitoring should be conducted at the drainage ditch to the east of, and hydraulically downgradient from the site; and it is recommended that at least three shallow/deep well pairs (one upgradient and two downgradient) be installed to facilitate groundwater monitoring.

Alternatives 5 through 8 are also recommended in the Pipeline Area. Assuming that the area of review (Alternative 5) does not locate any improperly abandoned wells, most of the work related to these tasks will probably involve establishing and maintaining proper vegetation cover in this area.

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